California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Compendium of Phase II Results

Booz·Allen & Hamilton Inc.
June 30, 1999

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INTRODUCTION

This compendium document represents the results of tasks undertaken by Booz·Allen & Hamilton Inc. on behalf of the California Department of Transportation (Caltrans), regarding the Transportation System Measures project. This initiative, for which the second phase has recently been completed, focused extensively on testing of indicators, as well as addressing the applicability of tools, market segmentation, and non-highway modes to performance measures.

This phase of the project continued to include a strong consensus building component, with regional agencies participating in System Measure Working Group sessions every other month. During these regular meetings, the Caltrans project management team and Booz·Allen presented progress reports, fielded questions, and incorporated comments generated in the discussions. In addition, draft deliverables were circulated to all working group members for review and comment. The final reports contained in this document incorporate all comments received by Caltrans and the Booz·Allen team.

The **State of the System Report** is presented first, since it is the next logical step in the support of both regional and inter-regional performance monitoring efforts.

All remaining reports document the research performed on specific indicators and other subjects relevant to the project. Executive summaries precede most of the reports.

The **Testing for Highway Mobility and Reliability Indicators** report investigates mobility and reliability indicators. The testing of mobility and reliability indicators identified in Phase I of the Performance Measures project was expanded to three major urban areas in the State. Automatic detection technologies can be applied to measure highway mobility and reliability in urban areas.

The **Applicability of Indicators to Transit** report analyzes how indicators for the safety / security, mobility, and reliability outcomes can be applied to the transit modes (e.g., bus, light rail, commuter rail). An industry survey of six properties supports the findings.

Applicability of Indicators to Goods Movement analyzed how each outcome related to the freight transportation in California. Both the trucking and freight rail industries were considered in the research.

The Economic Well-Being analysis is composed of two documents. First, the **Economic Well-Being Literature Review** provides an insight into existing research and applicability of economic models. Second, the **Economic Well-Being Testing Results** illustrates and draws conclusions regarding case study results from one regional economic model.

The **Travel Demand Model Review** is a survey of travel demand models used by regional planning agencies throughout California. The analysis focuses on the impacts travel demand models may have on performance measures given that they are administered by a wide range of agencies.

The **Applicability of Market Segmentation** report addresses how performance measures could address different approaches to market segmentation (e.g., trip purpose, trip mode, etc.).

The **Review of Caltrans Monitoring and Analysis Tools** summarizes existing Caltrans tools and instruments which are relevant to performance measures. Some of these tools are being integrated into a central Transportation System Network.

Finally, the **Implementation Plan** provides phasing information and general guidance regarding the next steps expected in order to successfully implement performance measures at Caltrans and with its partner agencies.

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
State of the System Report Design
Technical Memorandum

Booz·Allen & Hamilton Inc.
June 30, 1999

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EXECUTIVE SUMMARY

This document represents the technical memorandum for the State of the System design task in the Phase II of the Performance Initiative currently led by the California Department of Transportation (Caltrans). The task addresses research undertaken by Booz·Allen & Hamilton Inc. regarding the design of the State of the System Report.

The State of the System Report, developed jointly by State, regional and local stakeholders, is a document intended to…

> *add significant value to the overall planning and decision making process. Only by monitoring the system and understanding how previous investments contributed to its performance can lessons be learned and decisions be truly informed."*[1]

This report is intended as a blueprint for the design and composition of the State of the System Report. It includes background information on what the State of the System is and how it came to be. Guiding principles are provided for the Report. Finally, the report contains detailed design and format sections. Main recommendations include:

- Separate State of the System Reports should be developed for regional and state-wide (inter-regional) purposes, in accordance with the SB45 and the STIP funding frameworks.

- Not all performance outcomes need to be addressed by every region, only those outcomes deemed important for the region. Indicators not analyzed in the proof of concept phase, but viewed as more appropriate at the regional levels can augment and possibly even replace current indicators.

- Six main sections are recommended for inclusion:

  - Executive Summary
  - The Multi-Modal Transportation System
  - The Transportation Market
  - Performance Measures
  - Project Milestones
  - The Financial Picture.

  Design and format details for each section are provided in the report.

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1 *Phase I Transportation System Performance Measures, Final Report, California Department of Transportation, August 1998*

The State of the System reports represent a positive development and an innovative way for the State and the regions to monitor transportation performance at the project and system levels.

This document represents the technical memorandum for Task 7 in the Performance Measurement initiative currently led by the California Department of Transportation (Caltrans). The task addresses research performed by Booz·Allen & Hamilton Inc. regarding the design of a regional and statewide State of the System Report.

1. BACKGROUND

The performance measurement initiative currently underway represents an important management tool that enables Caltrans managers and other partner agencies understand how well their efforts (and investments) meet their goals and objectives.

1.1 Chronology

In the first phase of the initiative, nine key outcomes were developed for monitoring and forecasting use at the system level by regions and the State. Specific performance indicators for each outcome were proposed as well. The second phase of the effort, currently underway, focuses on testing the applicability of these indicators across different modes (e.g., transit, freight rail) and markets (e.g., freight versus person movement).

The Final Report of the Phase I Transportation System Performance Measures identifies State of the System reporting as the primary monitoring component for the performance measurement process:

> *"The use of system performance measurement in long range planning and improvement programming informs decision makers of the likely impacts of their decisions. As such, it represents an exercise in forecasting system performance given a portfolio of investments and expenditures. However, to fully take advantage of system performance measurement, periodic monitoring of activities is necessary. A State of the System Report, developed jointly by state, regional and local stakeholders adds significant value to the overall planning and decision making process. Only by monitoring the system and understanding how previous investments contributed to its performance can lessons be learned and decisions be truly informed. Moreover, monitoring reflects true conditions which can and should be used to improve forecasting capabilities."*

Simply put, the State of the System Report should summarize three questions to the public, decision makers and other stakeholders:

- where we are today
- what are the major trends
- what have we achieved during this cycle.

1.2 Regional Versus Statewide State of the System Report

Senate Bill 45, passed by the California State Legislature in 1997, enacted important changes regarding STIP funding. Two main provisions stand out:

- The State is responsible for 25 percent of STIP funds towards inter-regional projects; regions are responsible for 75 percent of STIP funds towards regional projects
- The State can recommend projects at the regional level, and in turn the regions can recommend projects at the State level.

The main result for performance measures is the need for two types of State of the System reports.

- The regional State of the System Report will address the performance of the regional multi-modal transportation system
- The statewide or inter-regional State of the System Report will address the performance of the inter-regional multi-modal transportation system.

Each of these reports can be similar in design, although regions may choose to focus on a subset of outcomes or include different performance indicators to address local and regional priorities.

1.3 Deployment

The State of the System report is part of the incremental deployment phase of the project. Once the initial testing and refinement phases are far enough along, State of the System reports can be produced at both the regional and inter-regional (i.e., State) levels.

Ideally, the monitoring provided through the State of the System Report can be done in conjunction with the bi-annual Regional Transportation Plan (RTP) updates at the regional level. Given the synergies, the regional State of the System Report could even become a part of the RTP. At the State level, the State of the System Report will build on the RTPs and would be most useful if provided about six months before the Inter-Regional Transportation Improvement Program (ITIP) cycle.

Initial deployment will also need to take into consideration enough lead time for the regions to be fully prepared and consensus building activities to run their course.

2. DESIGN CONSIDERATIONS

2.1 Guiding Principles

The State of the System Report must convey sufficient and meaningful summary state of the transportation information to the public, decision makers and other stakeholders. Specifically, it should:

- Track general transportation system, market developments and trends
- Present performance measurement results to the decision maker level
- Summarize Caltrans and regional agency project work completed over the course of the last period (e.g., since the last State of the System Report)
- Summarize the state of transportation improvement expenditures statewide and for the regions.

To the extent possible, the general format for the State of the System Report should be similar for the regional and the inter-regional report. This will facilitate aggregation of results from the regional to the State level as appropriate. It will also ensure that the most important categories of information are consistently addressed at both levels.

The development of both reports will require close partnership between Caltrans and regional agencies, particularly Metropolitan Planning Organizations:

- The regional State of the System reports will be developed by regional agencies. Caltrans should act as broker and facilitator in the process, while the regional agencies can help facilitate data collection from local agencies and the private sector as appropriate.

- The inter-regional State of the System Report will be the State's responsibility. In urban areas where inter-regional and regional movement can be hard to distinguish, regional agencies should help facilitate the collection of appropriate data, and vice versa.

The State of the System reports will be implemented in phases. Initially, the regional and inter-regional reports will reflect outcomes and performance indicators already tested in the initial testing and refinement phases. In addition, other guiding principles apply:

- Not all performance outcomes need to be addressed by every region, only those outcomes deemed important for the region

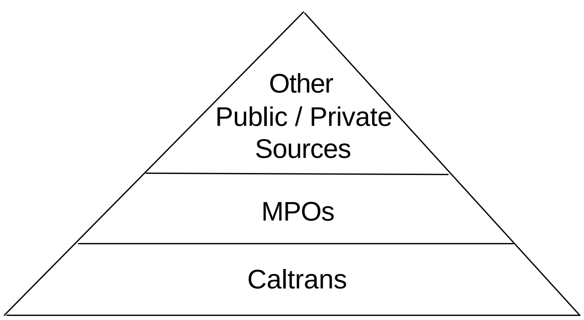
- Indicators not analyzed in the proof of concept phase, but viewed as more appropriate at the regional levels can augment and possibly even replace current indicators.

- Consensus building between Caltrans and the regions should continue an important dialogue and be strengthened especially at this time of implementation.

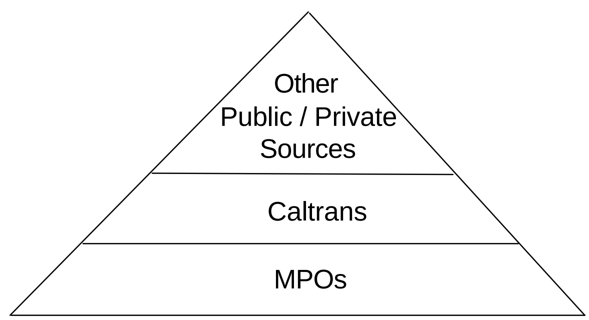
2.2 Data Collection

Sources of data for the State of the System reports will come from a variety of agencies. Existing and "free" sources of information are obviously desirable. In addition, it is important to seek the official keepers of base information, for example Caltrans for Interstate and state highway data.

The recommended framework for data collection can be summarized in the exhibits below. For the inter-regional State of the System Report, Caltrans would benefit from exhausting all internal data sources first prior to moving up the pyramid to the MPOs, then to other public agencies and operators and finally, to the private sector for data. For the regional State of the System Report, regions should also begin with internal sources, prior to seeking Caltrans, operator, facility and private sector data.



Inter-Regional Report Sources



Regional Report Sources

Specific sources of data for each section of the report are described in detail in Section 3, the design section of this document.

2.3 Supporting Sections

The State of the System Report must begin by addressing general transportation facts and trends in California. Information such as the infrastructure supply (i.e., number of freeway lane-miles), the extent of demands placed upon it (i.e., vehicle travel), and transportation project investments will provide the general context for "where we are", as well as major trends over the past few years. These facts are key barometers that generally speak well to decision makers and the general public.

The State of the System Report also provides an opportunity to summarize recent projects and project expenditures drawing on the STIP.

2.4 Performance Measures

System performance will provide the main message in the State of the System Report. The measures will help understand how previous investments contributed to system performance to truly inform decision makers and the general public. For example, if transportation officials are investing heavily to improve mobility in a fast growing corridor, they will want to know whether in fact the projects are having a mobility impact and the extent of that mobility improvement or deterioration.

The State of the System Report is the monitoring component of the performance measurement initiative. Monitoring reflects true conditions that need to be tracked over time. Monitoring will also help improve future forecasting capabilities. For some outcomes, performance indicators are more appropriate for forecasting, as in the case of economic well-being. Hence, decision makers will have to rely on a combination of monitoring and forecasting results as source for their information. The following table summarizes appropriateness of monitoring and forecasting for each of the nine outcomes in the framework:

Outcome	Monitoring	Forecasting
Mobility / Accessibility[2]	✓	✓
Reliability	✓	
Safety / Security	✓	✓
Cost Effectiveness		✓
Sustainability	✓	✓
Economic Well-Being		✓
Customer Satisfaction	✓	
Environmental	✓	✓
Equity		✓

Research to date performed by Caltrans is contained in a series of technical memoranda developed during phases I and II of the performance measurement initiative. These reports include:

- Applicability of Indicators to Highway
- Applicability of Indicators to Transit
- Applicability of Indicators to Goods Movement
- Economic Well-Being Literature Review
- Economic Well-Being Test Results
- Travel Demand Model Review

2 *Outcome areas listed in bold indicate measures that have been tested and can be incorporated into the first inter-regional State of the System Report*

- State of the System Report Design
- Sacramento Conference Paper: Pre-Testing Performance Measures
- Market Segmentation
- Review of Caltrans Monitoring and Analysis Tools.

Performance measures will be reported in one section of the State of the System and include as many outcomes as possible and/or desirable. The next section of this document addresses the specifics of proposed contents in the State of the System reports.

3. STATE OF THE SYSTEM REPORT DESIGN

Within the context of a phased implementation, the regional and inter-regional State of the System reports will contain the following sections:

- Executive Summary
- The Multi-Modal Transportation System
- The Multi-Modal Market
- Transportation System Performance Measures
- Project Milestones Achieved
- The Financial Picture

As discussed earlier, even though the general design is identical, there will be differences in content and emphasis between regional and inter-regional reports. To the extent possible, the different reports will share the same format.

3.1 Executive Summary

The Executive Summary section is intended simply as a brief synopsis of what the report represents and what the main performance indicators are revealing about transportation investments and the state of transportation in the region or State. It should not be more than three to four pages long.

The Executive Summary will address all performance areas tested in earlier phases and include a general discussion of the status of the State of the System process development. The Executive Summary for the inter-regional report should reference the regional reports, and vice-versa.

3.2 The Multi-Modal Transportation System

The section entitled Multi-Modal Transportation System is concerned with documenting and tracking the state of transportation supply in California.

In its broadest sense, supply represents the set of roads, railroad tracks, facilities, and vehicles which enable the movement of people and goods. Transportation supply has been likened to the "shell" that is left once all the demand (i.e., passengers and freight) have been put aside.

Vehicle supply also includes number of seats and vehicle frequencies, so that bus size, seat configuration and frequencies are all dimensions of transportation supply.

For the State of the System reports, supply must be addressed for four primary components spanning person and freight movement:

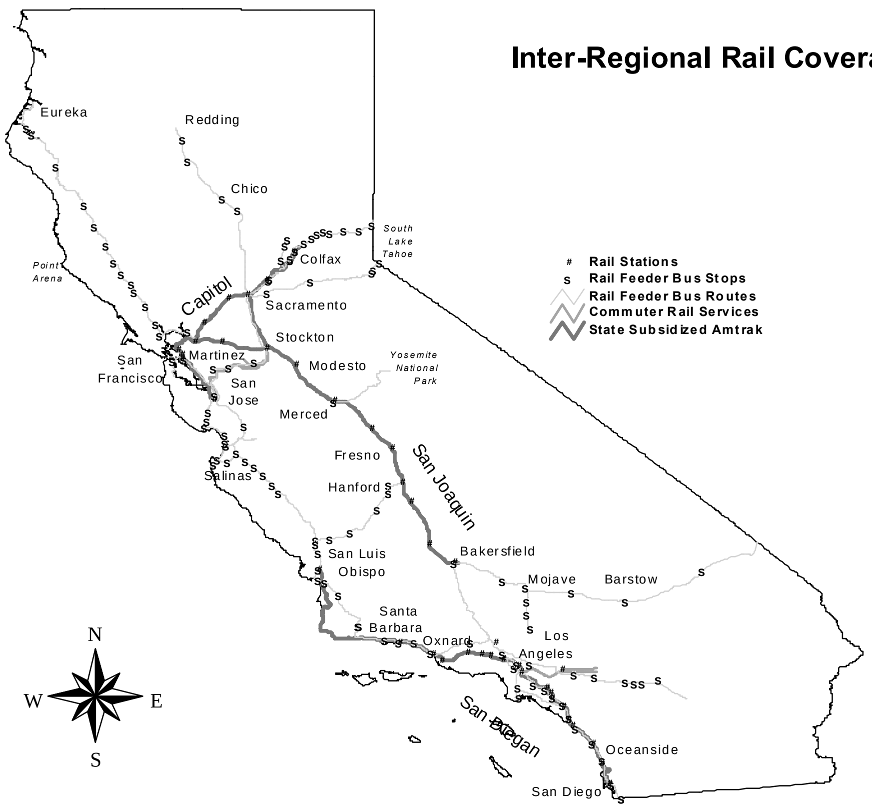
	Person Supply	Freight Supply
• Highway	✓	✓
• Bus	✓	
• Rail	✓	✓
• Intermodal Facilities	✓	✓

These components represent a combination of modes, infrastructure and facilities. The inter-regional and regional contents corresponding to these components is shown in the following table:

Component	Inter-Regional	Regional
Highway	• Interstates • State highways	• Interstates • State highways • Arterials • Local streets and roads
Bus	• Rail feeder bus (e.g., Capital Corridor) • Other publicly subsidized bus (e.g., Yolobus) • Private intercity bus (e.g., Greyhound)	• Local public service (e.g., San Francisco MUNI)
Rail	• State-subsidized rail (e.g., Capital Corridor) • Other publicly subsidized rail (e.g., Altamont Commuter Express) • Amtrak (e.g., Coast Starlight) • Freight rail (e.g. Union Pacific)	• Heavy rail (e.g., Los Angeles Red Line) • Light rail (e.g., Sacramento RT) • Commuter rail (e.g., JPB Caltrain) • Freight Short Lines (e.g., California Western Railroad)
Intermodal Facilities	• Major airports • Major seaports • Major inter-city rail stations • Major inter-regional bus stations • Intermodal freight facilities	• Regional rail stations • Regional bus stations

The definition of what constitutes a regional versus an inter-regional trip will be critical to the research and data analysis for the State of the System reports. The currently accepted boundary is the Regional Planning Agency limit. Clearly, some types of services (e.g., YoloBus) may have both regional and inter-regional components.

Maps will be critical in illustrating the coverage for each of the major supply components. The following map provides an illustration of what can be expected for the rail network in the inter-regional State of the System Report.



In addition, each listing identified in the main supply table will contain descriptive fields summarizing size, extent, capacity or limitations associated with that facility or modal network, as illustrated by the examples below:

- Highways
  - Number of center-lane miles
  - Capacity
  - Usage restrictions
- Bus

- Routes
- Service Frequency (headway)
- Schedule information
- Total fleet size[3]

- Rail

  – Total track length
  – Route locations
  – Schedule information
  – Total fleet size

- Intermodal facilities

  – Airport locations
  – Access roads
  – Connecting modes.

The table on the next page summarizes the specific fields recommended in more detail for each report. Note that the "Fields to Report" column applies to all categories identified. For example, center-lane miles and lane miles would both be presented for Interstates and State highways.

Furthermore, it is anticipated that some of the results will be numbers, such as lane miles, while other fields like as usage restrictions will be addressed through a summary paragraph.

3 *Vehicles registered / based in California (e.g., trucks)*

<table>
<tr><th rowspan="2">Component</th><th colspan="2">INTER-REGIONAL REPORT</th><th colspan="2">REGIONAL REPORT</th></tr>
<tr><th>Supply Categories</th><th>Fields to Report</th><th>Supply Categories</th><th>Fields to Report</th></tr>
<tr><td>Highway</td><td>• Interstates
• State highways</td><td>• Center-lane miles
• Lane miles
• Average lane capacity
• Usage restrictions (e.g., trucks, hazardous materials)</td><td>• Interstates
• State highways
• Arterials
• Local streets and roads</td><td>• Center-lane miles
• Lane miles
• Statement on average lane capacity
• Usage restrictions (e.g., trucks, hazardous materials)</td></tr>
<tr><td>Bus</td><td>• Rail feeder bus (e.g., Capital Corridor)
• Other publicly subsidized bus (e.g., Yolobus)
• Private intercity bus (e.g., Greyhound)</td><td>• Operators
• Fleet Sizes
• Routes
• Peak and off-peak headways</td><td>• Local public service (e.g., SF MUNI)</td><td>• Operators
• Fleet Sizes
• Routes
• Peak and off-peak headways</td></tr>
<tr><td>Rail</td><td>• State-subsidized rail (e.g., Capital Corridor)
• Other publicly subsidized rail (e.g., Altamont Commuter Express)
• Amtrak (e.g., Coast Starlight)
• Freight rail (e.g. Union Pacific)</td><td>• Operators
• Track-miles
• Routes
• Fleet Sizes
• Peak and off-peak headways</td><td>• Heavy rail (e.g., LA Red Line)
• Light rail (e.g., Sacramento RT)
• Commuter rail (e.g., San Diego Coaster)</td><td>• Operators
• Track-miles
• Routes
• Fleet Sizes
• Peak and off-peak headways</td></tr>
<tr><td>Intermodal Facilities</td><td>• Major airports
• Major seaports
• Major intermodal freight facilities
• Major inter-city rail stations
• Major inter-regional bus stations</td><td>• Locations
• Access roads
• Access freeways
• Connecting modes (with maps)
• Usage restrictions</td><td>• Regional rail stations
• Regional bus stations</td><td>• Locations
• Access roads
• Access freeways
• Connecting modes (with maps)
• Usage restrictions</td></tr>
</table>

Sources for the multi-modal transportation system will, for the most part, be Caltrans and the MPOs. Limited follow-up with public and private operators, as well as with the intermodal facilities, may be required.

Specific sources by field are shown below.

	INTER-REGIONAL REPORT		REGIONAL REPORT	
Component	**Fields to Report**	**Source**	**Fields to Report**	**Source**
Highway	• Center-lane miles • Lane miles • Average lane capacity • Usage restrictions	• Caltrans	• Center-lane miles • Lane miles • Average lane capacity • Usage restrictions	• Caltrans for Interstates and State highways • MPOs and Cities for arterials and local roads
Bus	• Operators • Fleet Sizes • Routes • Peak and off-peak headways	• MPOs • Operators	• Operators • Fleet Sizes • Routes • Peak and off-peak headways	• MPOs • Operators
Rail	• Operators • Track-miles • Routes • Fleet Sizes • Peak and off-peak headways	• Caltrans Rail Program • MPOs • Operators	• Operators • Track-miles • Routes • Fleet Sizes • Peak and off-peak headways	• MPOs • Operators
Intermodal Facilities	• Locations • Access roads • Access freeways • Connecting modes • Usage restrictions	• Caltrans • MPOs • Facilities	• Locations • Access roads • Access freeways • Connecting modes • Usage restrictions	• MPOs • Facilities

The lists of fields provided on the previous pages are intended as a guide to both the regions and Caltrans for the inter-regional report. There may be instances, however, where regions wish to report on additional facility types. For example, regional freight rail systems could be reported.

3.3 The Multi-Modal Market

The Multi-Modal Market section will summarize the state of transportation demand in California. Market or demand information represents the usage placed on the modal network and facilities by people and goods. Examples of demand quantities include trips made, people carried, vehicle miles traveled, tons of freight carried and ton-miles traveled.

Market information provides a basis for reviewing performance results. Monitoring the evolution of transportation demand will provide perspective and help decision makers and the public understand the relative performance summarized in the third section of the State of the System Report.

In addition, tracking the evolution of the multi-modal market over time will enable planners to analyze trends and to empirically forecast future market conditions.

The multi-modal market section will be tailored and aggregated for the regional and inter-regional State of the System reports. Focus should be placed on addressing the characteristics of who is living in the region, how they travel, and the extent to which they travel. Four sub-sections are proposed for this part of the report:

- Demographics
- Land use and production
- Transportation mode share
- Major origin-destination flows
- Annual statistics.

Demographics information should include a measure of the population by region. In the regional reports, the data can be aggregated first at the county level. Additional demographics suggested for the section include a measure of employment (e.g., jobs and employment rates), and car ownership (e.g., cars registered per County, average vehicles per household).

The section on land use and production should represent the equivalent for population and demographics for the person movement market for freight. In this section, the goal is to document major centers of production and the land use that supports goods movement activity.

Transportation mode share reflects the distribution in mode traveled: percentage of single occupancy vehicle trips, high occupancy vehicle (HOV), transit, walk / bike, etc.

The goal in addressing this element is to provide the reader a comprehensive view of the percent modal share by region and for the inter-regional system.

Major origin-destination flows focus on the geographic distribution of travel demand. At the State level, major inter-regional flows can be mapped both for person and goods movement. These flows can be further documented by trip purpose. The same analysis may be more difficult at the regional level, especially for freight and goods movement.

Finally, the Annual Statistics sub-section will state the extent to which people and goods have traveled in the region and State for California travel only. Statistics will be compiled for the latest year and will include:

Person Market
- Vehicle miles traveled (for all modes)
- Person miles traveled (for all modes)

Goods Movement Market
- Tons of goods moved (for all modes)
- Ton-miles traveled (for all modes).

It is anticipated that some new data collection will be required for several of the data elements identified above. Potential sources for each category of information are presented in the table below.

Sub-Section	Data	Source
Demographics	Population	• Department of Finance • Regional Planning Agency (regional report), e.g., Association of Bay Area Governments
	Employment	• Department of Labor, RPA
	Car Ownership	• Department of Motor Vehicles
Land Use and Production	Land Uses Centers of Production	• Caltrans • Department of Commerce
Mode Share	Person Market	• Caltrans, MPOs (State) • MPOs (region)
	Freight Market	• Caltrans
Major Origin-Destination Flows	Person Market	• Caltrans, MPOs (State) • MPOs (region)
	Freight Market	• Caltrans
Annual Statistics	Person Market	• Caltrans, MPOs (State) • MPOs (region)
	Freight Market	• Caltrans

3.4 Transportation System Performance Measures

The Performance Measures section will be the cornerstone of the State of the System Report. The section will present an at-a-glance summary of the region/State performance for each outcome in the performance evaluation framework.

Initially, the section will address only those outcomes for which performance indicators have been tested in the initial testing and/or refinement phases of the performance measure initiative. This list currently includes the following:

- Safety / Security
- Mobility / Accessibility
- Reliability

- Environmental Quality.

As the refinement phase proceeds, other indicators such as economic well-being, cost effectiveness, sustainability, customer satisfaction and equity may be added.

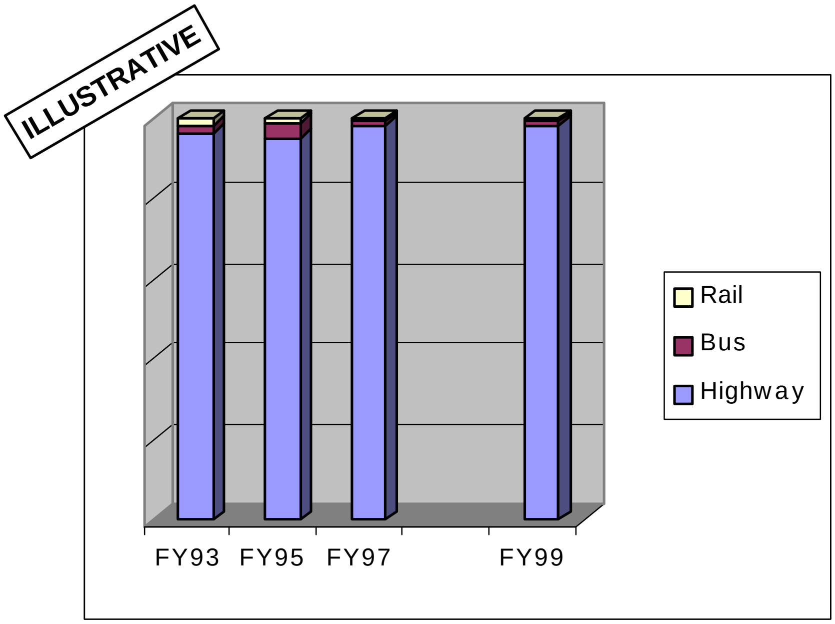
3.4.1 Safety / Security

The safety / security outcome will be presented first. Performance indicators identified and tested for safety and security include:

- Safety totals (accidents, fatalities)
- Safety rates (accidents, fatalities)
- Crime events (transit only).

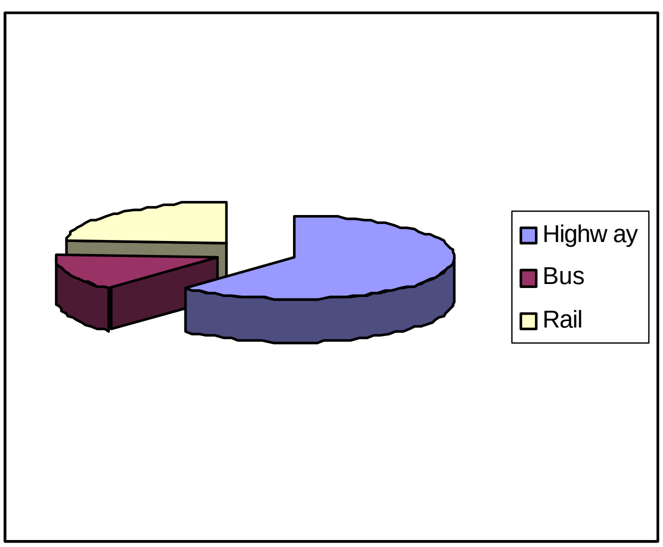
In addition to providing the **safety** data for the last year, it will be useful to display a graphical representation of the trend over the last several years as shown below for total accidents.

TOTAL ANNUAL ACCIDENTS BY MODE
REGION A



In addition, displaying the current mode share of accidents, normalized by person mile traveled will add perspective.

ACCIDENT MODE SHARE
(normalized by Person Mile Traveled)



This procedure will be repeated for safety rates.

Finally, the **security** indicator will only be reported for transit, since security is most applicable to, and routinely measured for, the transit mode.

Several persons on the System Measures Advisory Group inquired about tracking security for highways. The California Highway Patrol (CHP) collects statistics on security offenses in California. The events include 11 categories ranging from "Assault with a deadly weapon" to "Brandishing a firearm". Unfortunately, the events are grouped by CHP beat, with no geographical linkage to Caltrans highways. Therefore, at this time the security indicator will apply to transit only.

With both the regional and inter-regional reports, the safety indicators should be shown separately for each mode and aggregated for the system.

MODE	**SAFETY DATA SOURCES**	**SECURITY DATA SOURCES**
Highway - Auto - Truck	Caltrans	Not applicable
Rail - Passenger Rail - Freight Rail	Public Utility Commission	Federal Transit Administration, Federal Railroad Administration, Operators
Bus - Local Bus - Inter-City Bus	Individual Operators	Federal Transit Administration, Operators

3.4.2. Mobility / Accessibility

The mobility / accessibility outcome will be presented next. The indicators successfully tested for this outcome are:

- delay
- access to transportation system

Please note that travel time was initially identified as a meaningful performance indicator for mobility. Travel time can currently be computed for the highway (and trucks) on a segment by segment basis in urban areas. However, the data available for highways presently do not support the calculation of an aggregate travel time calculation at this time. It is anticipated that average travel time will be used in the longer-term when better data collection methodologies become available.

To address **mobility**, the report will present delay statistics: total delay, delay trends, and delay causes by mode:

- Delay for *highways* and *freight* can be obtained directly for both from the Highway Congestion Monitoring Program report (i.e., HICOMP report)

  The following table illustrates an example of delay compilation at the County level which can be aggregated for each region and then for the State as a whole. In addition to the fields shown, the delay can be normalized quite easily, either by VMT or per capita.

ILLUSTRATIVE

County	Annual Delay (Hrs)	Daily Delay (Hrs)	Congested Miles
Alameda	3312776	41800	83
Contra Costa	1942421	14000	56
El Dorado	32639	93	10
Fresno	18646	75	2
Marin	1152476	7200	22
Orange	9251526	78906	204
Placer	26224	382	3
Riverside	3955952	15666	55
Sacramento	2145458	7335	85
San Bernardino	6005787	13702	35
San Diego	509076	42354	
San Francisco	1409634	6900	20
San Joaquin		2711	19
San Mateo	1542154	9800	33
Santa Clara	3080405	29300	93
Santa Cruz		2020	19
Solano	101262	400	1
Sonoma	526367	2800	19

- *Transit* delay can be estimated by using the approach outlined in the Applicability of Indicators to Transit technical memorandum (i.e., difference between schedule and optimal travel time)

The sources for calculating delay are numerous and well documented in previous Performance Measure program technical memoranda: <u>Highway Mobility and Reliability</u>, <u>Applicability of Indicators to Transit</u>, <u>Applicability of Indicators to Goods Movement</u>. The main sources include:

- The *Highway Congestion Monitoring Program Report* provides delay estimates for counties and districts throughout the state.

  – This information is provided in both graphical and tabular form

– Caltrans' traffic count books can be used to estimate the number of trucks traveling along congested segments which can be used to measure the impact of delay on freight and goods movement.

- Transit schedules for inter-regional service and average speed data can be used to calculate delay for inter-regional transit services.

- Regional transit delay will have to be calculated using data collected from local area operators:

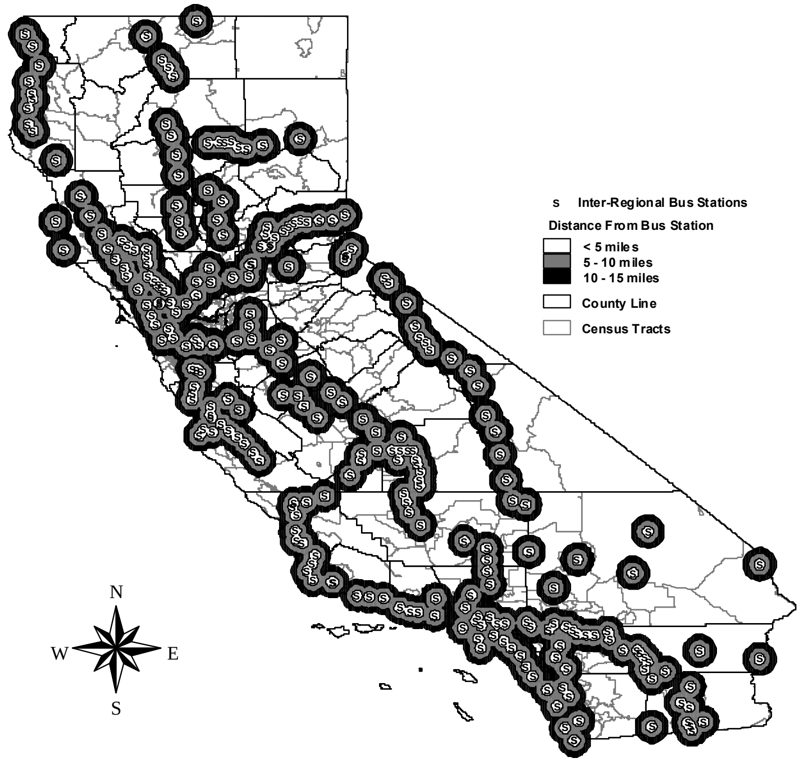
  - schedule information
  - route length
  - posted speeds along route

Accessibility will be presented in terms of access to the transportation system:

- *Highway* accessibility will be measured as the percent of the population within specified distance from the regional and inter-regional transportation system access points (e.g., highway ramp)

- *Transit* accessibility will measure the percent of the population living within specified distances of major regional or inter-regional transit facilities or airports

  The following map illustrates how the distance criteria can be applied for inter-regional bus stations, as part of the inter-regional State of the System Report.



- *Freight* accessibility will be measured as the accessibility to intermodal facilities (e.g., ports) with regards to parking / staging areas and hours of operation.

It is envisioned that accessibility to the transportation system will be reported in the aggregate, by modes, and possibly by socio-economic grouping.

- Accessibility will be measured by calculating the percentage of the population residing specified distances from significant regional and inter-regional transit facilities or airports, for example a mile[4]

- Accessibility can be calculated by using geographic information system tools and readily available census (1990 or 2000) or updated regional demographic information

- Market segment data is also readily analyzed using this approach. Using census data, socio-economic profiles can be used to dis-aggregate the accessibility indicator therefore presenting accessibility by population groups.

4 *Both regions and the State should also consider time-based rings from facilities for access (e.g., 10 minutes, 30 minutes)*

Sources of accessibility data include:

MODE	ACCESSIBILITY DATA SOURCES
Highway - Auto	MPOs Operators Airports
Transit - Bus - Passenger Rail - Inter-City Rail	MPOs Operators
Freight - Truck - Rail	Facilities (e.g., ports) Operators Caltrans

3.4.3 Reliability

State of the System reporting on the reliability outcome will come next. The only indicator for reliability is common across all modes and is defined as the variability of travel time.

Calculating reliability requires a statistical valid sample of data for highways (and truck freight) while transit reliability can be measured using commonly collected data from transit operators.

The main source for highway reliability data consists of inductive loop information collected by Caltrans. The Caltrans loop detectors provide real-time data for most urban areas throughout the state that can be used to calculate highway reliability. Although detector coverage gaps exist and data consistency is an issue for some areas, Caltrans has embarked on a program to improve the quality and coverage of loop detectors throughout the state

Aggregated at 15-minute intervals, extensive data can be collected throughout the year to evaluate system reliability seasonally and by time-of-day. The reliability thus calculated for highways is also the reliability for trucks transporting goods on the same network.

The following table illustrates sample reliability data for State Highways in Orange County. It is based on loop detector data collected for the AM peak in early 1999. The data was initially collected at 30 second intervals and aggregated to 15 minutes intervals. It has been aggregated here by route for the entire morning peak. For the State of the System Report, the data can be further aggregated for the year, by County and ultimately by region.

SEGMENT INFORMATION				RELIABILITY			
Route		From	To	Standard Deviation (Minutes)	Percent Variation	Length of Segment (Miles)	Travel Time (Minutes)
22	W	Tustin	Valley View	0.43	4%	11.81	10.73
22	E	Garden Grove	Tustin	3.06	25%	10.93	12.33
91	W	Gypsum Canyon	La Palma	2.28	18%	11.42	12.93
405	N	Harbor	Waner	0.22	4%	5.93	5.60
5	S	Main Street	Sand Canyon	1.38	13%	10.72	10.50

Transit reliability can be calculated by using system on-time performance. On-time performance is a commonly collected indicator, used by most transit agencies in California. This measure can be evaluated for other modes (e.g., Amtrak, intercity bus) by comparing actual run times to scheduled run times.

3.4.4 Environmental Quality

Environmental quality is an outcome that can be reported in the regional and inter-regional State of the System reports immediately due to its reliance on existing reporting mandates to the California Air Resources Board and the Environmental Protection Agency.

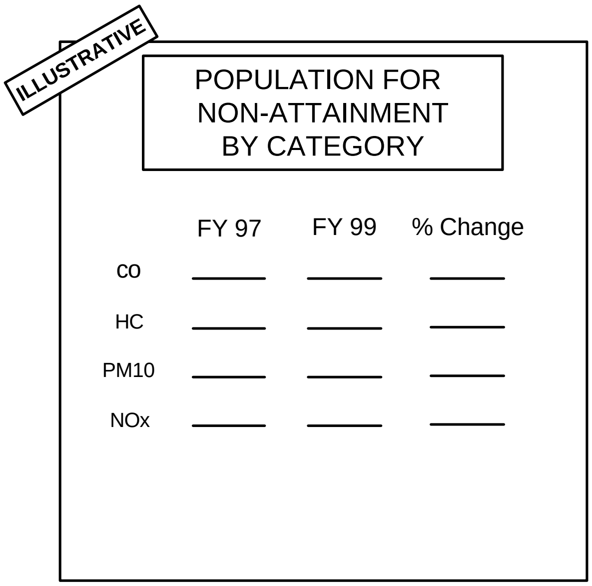
The difference with reporting environmental quality in a State of the System report lies in two areas:

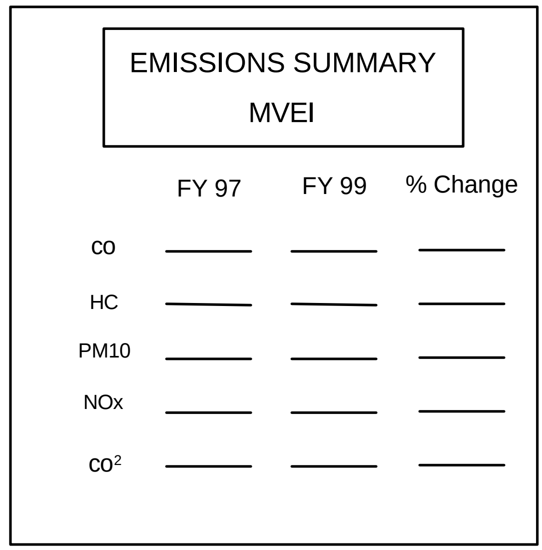
- first, aggregation is desired, moving from a project focus to a region or state focus

- second, the reporting is more meaningful if discussed vis-à-vis non-attainment areas and similar environmental "target" areas.

When the indicators for environmental quality was developed during Phase I of the performance measurement initiative, the consensus was not to "reinvent the wheel". As such, the conformity/compliance indicator was to report current air quality and environmental standards such as those required by NEPA, CEQA, the Clean Air Act, and the Clean Water Act. The second indicator proposed, the livability index, has not been tested and is still being investigated.

The goal for the conformity/compliance indicator is to monitor progress towards attaining statutory standards for both the regional and inter-regional System. The compliance statistics must be aggregated on a regional and state-wide basis for inclusion in the State of the System reports. In addition, emission totals can be shown in the State of the System Report in contrast with population growth by non-attainment area (shown below). This provides immediate background to help explain environmental quality performance.





The environmental performance section of the State of the System Report will begin with an attainment status sheet for the State or the detailed region as appropriate. Environmental performance indicators will be completed through the Caltrans Environmental Program, with follow-ups to regional Air Quality Management Districts if necessary.

At the last advisory meeting, the Southern California Association of Governments (SCAG recommended adding vehicular emissions from the Motor Vehicle Emissions Inventory (MVEI) to State and Federal measures.
In the State of the System Report, the emissions will be estimated through the Air Resources Board. However, there can be no differentiation between "regional" and "inter-regional" emissions based on current data.

3.5 Project Milestones Achieved

The next major section in the State of the System Report is concerned with major project milestones achieved in the last cycle. The section is intended to provide decision makers with a summary of the status of different projects ongoing or complete in their region/State.

For maximum benefit, key provisions for the milestones should include:

- projects completed, including budget and schedule adherence
- projects still under way, including estimated budget and schedule adherence
- succinct explanations for major deviations and recovery plan

- project impacts on performance outcomes discussed in previous sections

It is worth noting that certain projects under the final stages of construction or recently completed projects may show more of an adverse impact due to the construction than benefit of being open and available to citizens. Such cases should documented to the extent possible.

Given the large number of projects at the regional and inter-regional levels, some threshold level for cut-off is needed. As an example of a reasonable cut-off, projects under $10 million could be exempted from reporting in this section of the regional State of the System Report, and under $50 million for the inter-regional report. These thresholds can be revised as needed. In addition, aggregate totals (irrespective of project size) by county should be included to round out the picture.

The contents of this section for the inter-regional system may be addressed by current initiatives at Caltrans (e.g., CTIS). This section on project milestones is also consistent with current State emphasis on project delivery and relates indirectly to the cost effectiveness outcome.

3.6 The Financial Picture

The last major section proposed for the State of the System Report design concerns the financial summary. The financial picture section should discuss sources and uses of funds as in typical planning exercises

Sources of funds would include the following:

- Federal (e.g., TEA-21 by category)
- State (e.g., TDA, bond measures)
- Regional (e.g., county sales tax)
- Local sources (e.g., City general funds)

Uses of funds would include:

- Capital expansion
- Capital rehabilitation
- Operating
- Maintenance

Though the STIP only addresses improvement investments, the State of the System Report is envisioned to be more comprehensive.

4. DETAILED FORMAT

This section provides a detailed design format for the regional and inter-regional State of the System reports.

4.1 Regional State of the System Report

1. Executive Summary

2. The Multi-Modal Transportation System
   2.1 Highway
      2.1.1 Interstates
      2.1.2 State Highways
      2.1.3 Arterials
      2.1.4 Local streets and roads
   2.2 Bus
   2.3 Rail
      2.3.1 Light Rail
      2.3.2 Heavy Rail
      2.3.3 Commuter Rail
      2.3.4 Freight Short Lines
   2.4 Intermodal Facilities
      2.4.1 Regional Rail Stations
      2.4.2 Regional Bus Stations

3. The Transportation Market
   3.1 Demographics
      3.1.1 Population
      3.1.2 Employment
      3.1.3 Car Ownership
   3.2 Land Use and Production
   3.3 Transportation Mode Share
      3.3.1 Person Market
      3.3.2 Freight Market
   3.4 Major Origin-Destination Flows (optional)
      3.4.1 Person Market
      3.4.2 Freight Market
   3.5 Annual Statistics
      3.5.1 Person Market
      3.5.2 Freight Market

4. Performance Measures
   4.1 Safety / Security
      4.1.1 Safety Totals
      4.1.2 Safety Rates
      4.1.3 Crime Events

4.2 Mobility / Accessibility
- 4.2.1 Delay
  - 4.2.1.1 Total Delay by Mode
  - 4.2.1.2 Delay Trends by Mode
  - 4.2.1.3 Delay Causes by Mode
- 4.2.2 Access to Transportation System
  - 4.2.2.1 Highway
  - 4.2.2.2 Transit
  - 4.2.2.3 Freight

4.3 Reliability
- 4.3.1 Highway
- 4.3.2 Transit

4.4 Environmental Quality
- 4.4.1 Conformity / Compliance to State Regulations
- 4.4.2 Conformity / Compliance to Federal Regulations

5. Project Milestones

6. The Financial Picture

4.2 Inter-Regional State of the System Report

1. Executive Summary
2. The Multi-Modal Transportation System

2.1 Highway
- 2.1.1 Interstates
- 2.1.2 State Highways

2.2 Bus
- 2.2.1 Rail Feeder Bus
- 2.2.2 Other Publicly Subsidized Bus
- 2.2.3 Private Intercity Bus

2.3 Rail
- 2.3.1 State Subsidized Rail
- 2.3.2 Other Publicly Subsidized Rail
- 2.3.3 Amtrak
- 2.3.4 Freight Rail

2.4 Intermodal Facilities
- 2.4.1 Major Airports
- 2.4.2 Major Seaports
- 2.4.3 Major Intermodal Freight Facilities
- 2.4.4 Major Inter-Regional Bus Stations
- 2.4.5 Major Inter-City Rail Stations

3. The Transportation Market

- 3.1 Demographics
  - 3.1.1 Population
  - 3.1.2 Employment
  - 3.1.3 Car Ownership
- 3.2 Land Use and Production
- 3.3 Transportation Mode Share
  - 3.3.1 Person Market
  - 3.3.2 Freight Market
- 3.4 Major Origin-Destination Flows
  - 3.4.1 Person Market
  - 3.4.2 Freight Market
- 3.5 Annual Statistics
  - 3.5.1 Person Market
  - 3.5.2 Freight Market

4. Performance Measures
   - 4.1 Safety / Security
     - 4.1.1 Safety Totals
     - 4.1.2 Safety Rates
     - 4.1.3 Crime Events
   - 4.2 Mobility / Accessibility
     - 4.2.1 Delay
       - 4.2.1.1 Total Delay by Mode
       - 4.2.1.2 Delay Trends by Mode
       - 4.2.1.3 Delay Causes by Mode
     - 4.2.2 Access to Transportation System
       - 4.2.2.1 Highway
       - 4.2.2.2 Transit
       - 4.2.2.3 Freight
   - 4.3 Reliability
     - 4.3.1 Highway
     - 4.3.2 Transit
   - 4.4 Environmental Quality
     - 4.4.1 Conformity / Compliance to State Regulations
     - 4.4.2 Conformity / Compliance to Federal Regulations

5. Project Milestones
6. The Financial Picture

California Department of Transportation

Transportation System Information Program

Transportation System Performance Measures
Proof-of-Concept Testing for Highway Mobility and Reliability Indicators

Technical Memorandum

Booz·Allen & Hamilton Inc.

June 30, 1999

TABLE OF CONTENTS

BOOZ·ALLEN & HAMILTON INC. EXPANDED THE HIGHWAY MOBILITY AND RELIABILITY PROOF-OF-CONCEPT TESTING FROM PHASE I TO OTHER METROPOLITAN AREAS IN THE STATE

- In Phase I Booz·Allen tested the highway mobility and reliability indicators for a 14-mile segment of I-405 in Los Angeles
- In Phase II this testing was expanded to the San Francisco Bay Area, Orange County, and the San Diego metropolitan area
- The primary finding is that automatic detection technologies can be applied to measure highway mobility and reliability in urban areas
- Reliability, as measured by the variability of travel time, can exceed 50 percent on some segments in the state
- The causes of, and the solutions to, highway system reliability problems remain to be answered. The highway reliability indicator can be used as the starting point for answering these unanswered questions

DETAILED FINDINGS AND RECOMMENDATIONS FOR MOBILITY AND ACCESSIBILITY…

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	RECOMMENDATIONS
Mobility/ Accessibility	Delay (Lost Time)	Phase I: • In Los Angeles, I-405 SB travel time varied from 34% to 39% in the AM peak. Delay reached nearly 30 minutes • Northbound travel time varied by 15% at most. Delay was less than 4 minutes • Travel time on the off-peak direction varied by 11% in the AM period	Highway segments with fewer interchanges experience higher performance levels than segments with more closely spaced interchanges	• Expand testing to other metropolitan areas to identify reliability thresholds and explore how reliability varies on other facilities • Assess mobility data availability for non metropolitan areas • Develop a baseline lost time for the region/State to monitor, forecast, and report delay for improvements
Reliability	Travel Time Variability	Phase II: • Loop detector data can be used to estimate highway performance • There are some coverage gaps in the State's loop detector network	Loop detectors provide speed and volume data that can be translated into travel time, delay, and reliability information	• Explore potential benefits from developing a consistent State application for analysis of loop detector data • Expand analysis and explore how other factors affect variability • Develop a baseline travel time reliability for region/State to monitor, forecast, and report time reliability for improvements

THIS TECHNICAL MEMORANDUM PRESENTS THE PROOF-OF-CONCEPT TESTING RESULTS FOR HIGHWAY MOBILITY AND RELIABILITY

- This memorandum will introduce indicators to measure highway mobility and reliability
- The methodology used in Phase I and Phase II of the Performance Measures Program will be outlined
- The realized data collection effort and data processing procedures will be discussed
- Findings for the San Francisco Bay Area, San Diego, and Orange County will be presented
- An example of a potential application will be provided and the conclusions of this effort will be discussed

MOBILITY AND RELIABILITY ARE TWO OUTCOMES USED TO MEASURE HIGHWAY PERFORMANCE

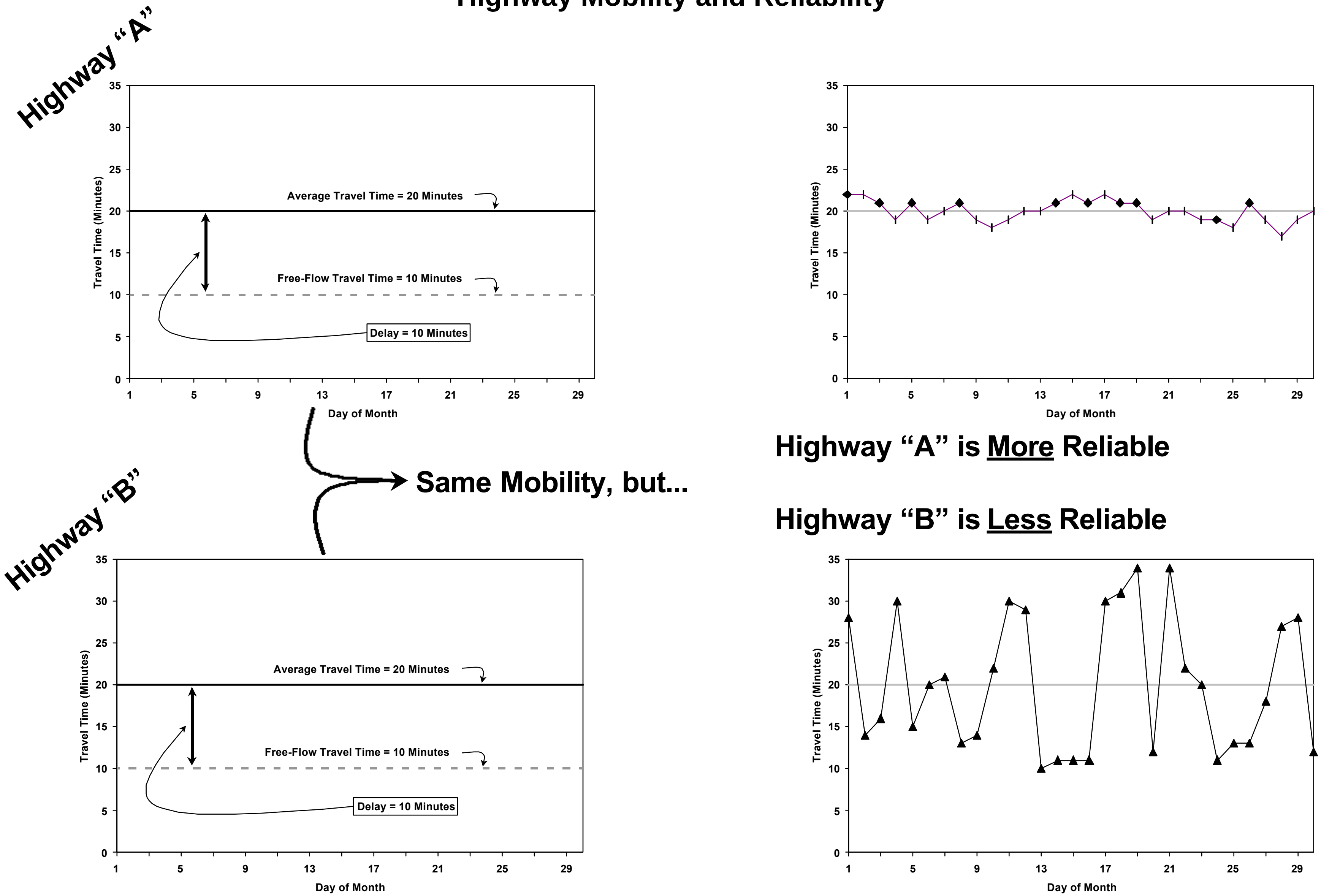
- Mobility is defined in terms of average point-to-point travel times and travel delay. Delay is the additional time spent traveling due to less than optimal circumstances

  Delay is calculated by subtracting free-flow travel time from the average travel time. The free-flow travel time is determined by the posted speed (i.e., Free-flow Travel Time = Distance ÷ Posted Speed). If the distance is 10 miles and the posted speed is 65 mph, then the free-flow travel time is 9.2 minutes ($9.2\text{min} = .154\text{hour} \times 60\frac{\text{min}}{\text{hour}} = \left(\frac{10\text{miles}}{65\text{mph}}\right) \times 60\frac{\text{min}}{\text{hour}}$). A comparison of delay calculations is presented in the illustration on page II-2F

- Reliability is the level of variability in transportation service between the expected travel time and the actual travel time. The relationship between delay and reliability is shown on the illustration on page II-2F

  Reliability can be calculated by using statistical tools. The standard deviation is one such tool that provides an estimate of how much the travel time on any given day will "deviate" from the average travel time. It provides the probable range of time that a motorist will arrive within his or her scheduled time. Dividing the standard deviation by the average time spent traveling produces the percent variability of a highway segment

Highway Mobility and Reliability



IN PHASE I BOOZ·ALLEN TESTED THE HIGHWAY MOBILITY AND RELIABILITY INDICATORS FOR A 14-MILE SEGMENT OF I-405 IN LOS ANGELES

- In the I-405 test case, the average travel time in the morning peak travel direction (Southbound) was found to vary between 34 and 39 percent. Northbound variability varied by no more than 15 percent in the morning commute

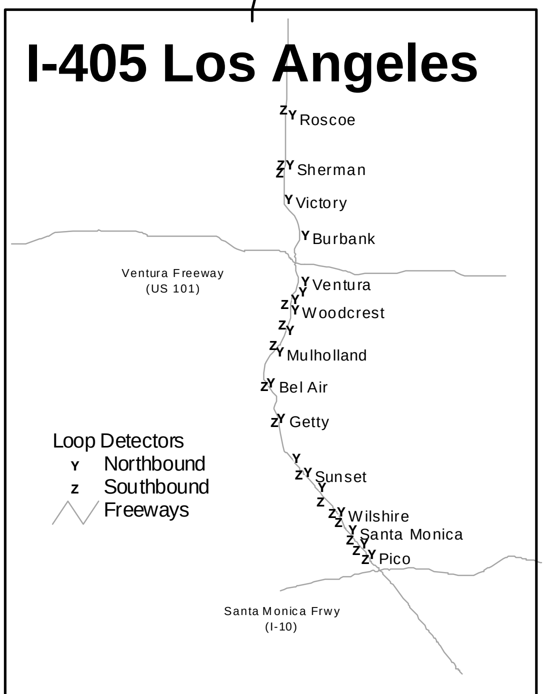
- Delay in the morning peak travel direction (southbound) nearly reached 30 minutes over the 14-mile stretch of roadway. Northbound (off-peak) delay was less than four (4) minutes

- The off-peak direction varied by only 11 percent in the AM period

- Mobility and reliability varied by segment. Segments with few interchanges experienced higher levels of mobility and lower variability in travel times, while those with closely spaced interchanges demonstrated degraded performance

IN PHASE II BOOZ·ALLEN EXPANDED TESTING TO OTHER AREAS IN THE STATE TO IDENTIFY RELIABILITY THRESHOLDS AND TO SEE HOW RELIABILITY VARIES IN DIFFERENT REGIONS

Proof-Of-Concept Results for Phase I



Southbound
Roscoe Blvd. To I-10
Distance = 14.1 Miles

	Time of Day	MOBILITY: Average Travel Time (Minutes)	MOBILITY: Average Delay (Minutes)	RELIABILITY: Standard Deviation (Minutes)	RELIABILITY: Percent Variation
AM	5:00-6:00 AM	24.5	12.0	9.6	39%
AM	6:00-7:00 AM	35.5	23.0	12.2	34%
AM	7:00-8:00 AM	41.0	28.5	14.0	34%
AM	8:00-9:00 AM	36.2	23.7	14.3	39%

Northbound
Pico Blvd. To Roscoe Blvd.
Distance = 14.0 Miles

	Time of Day	MOBILITY: Average Travel Time (Minutes)	MOBILITY: Average Delay (Minutes)	RELIABILITY: Standard Deviation (Minutes)	RELIABILITY: Percent Variation
AM	5:00-6:00 AM	15.2	2.5	0.7	4%
AM	6:00-7:00 AM	14.9	2.2	1.2	8%
AM	7:00-8:00 AM	16.1	3.4	2.5	15%
AM	8:00-9:00 AM	16.4	3.8	1.8	11%

TO DEVELOP THE HIGHWAY RELIABILITY INDICATOR DATA FROM CALTRANS LOOP DETECTORS WERE USED

- A system of loop detectors uses electronic wires or "loops" embedded in the pavement to create a magnetic field that can detect vehicles
- Loop detectors count the vehicles that pass over them and the amount of time that the loops are "occupied" by those vehicles
    - Loops placed in pairs a known distance a part can count the time it takes a vehicle to pass between them and calculate the travel speed
    - Single loops can estimate speeds by measuring the "occupancy" and volume and using some calibration factors
- Data is sent to a central processing computer, usually in 30-second intervals
- There exist a number of applications to aggregate and analyze loop data, and no District uses or processes the data in the same way
- Booz·Allen developed own database applications to process the data for this project

BOOZ·ALLEN COMPLETED DATA COLLECTION AND PERFORMED AN ASSESSMENT FOR THE SAN FRANCISCO BAY AREA, SAN DIEGO AND ORANGE COUNTY

- Caltrans District 4 in Oakland provided the study team with 44 days of loop detector data to use for this analysis. Data was provided for all weekdays -- September through November. Over 2.5 gigabytes of data were processed

- District 11 in San Diego provided over 20 days of data -- binary loop data was collected for weekdays between November and December. The data collected resulted in over 1.9 million records of useable data

- The University of California at Berkeley's Partners for Advanced Transit and Highways (PATH) program received 10 days of useable data for January 1999 from District 12 in Orange County which was to Booz·Allen for analysis

- Data were aggregated to 15-minute intervals for ease of use

- Caltrans District 7 in Los Angeles is transitioning to new software that will allow better access to their data. The transition was not completed in time for this analysis

Candidate Corridors

Corridor / Route	Direction	District	Counties	Location		Total Miles	Status June 30, 1999
				From	To		
I-80	WB	4	Contra Costa/San Francisco	Appian Way	4th Street	7.6	**Completed**
SR101	NB & SB	4	San Mateo/San Francisco	Burlingame	Central Frwy	13-15*	**Completed**
SR24	EB &WB	4	Alameda/Contra Costa	MLK Blvd.	I-680	11.0*	**Completed**
I-8	WB	11	San Diego	Waring	Los Coches	12.9	**Completed**
SR94	WB	11	San Diego	SR125	28th Street	7.8	**Completed**
I-405	NB	12	Orange	Harbor	Warner	5.9	**Completed**
SR-22	EB &WB	12	Orange	Tustin	Garden Grove	10-12*	**Completed**
SR101	NB & SB	4	Marin	SR37	I-580	9.1	Eliminated
SR41	NB & SB	6	Fresno	Friant Ave.	SR99	10.8	Eliminated
I-105/110	EB/WB & SB/NB	7	Los Angeles	El Segundo	Downtown	14.9	Eliminated
SR101	NB or SB	7	Los Angeles	Calabasas Rd.	Downtown	30.3	Eliminated

*** - Estimated Mileage.**

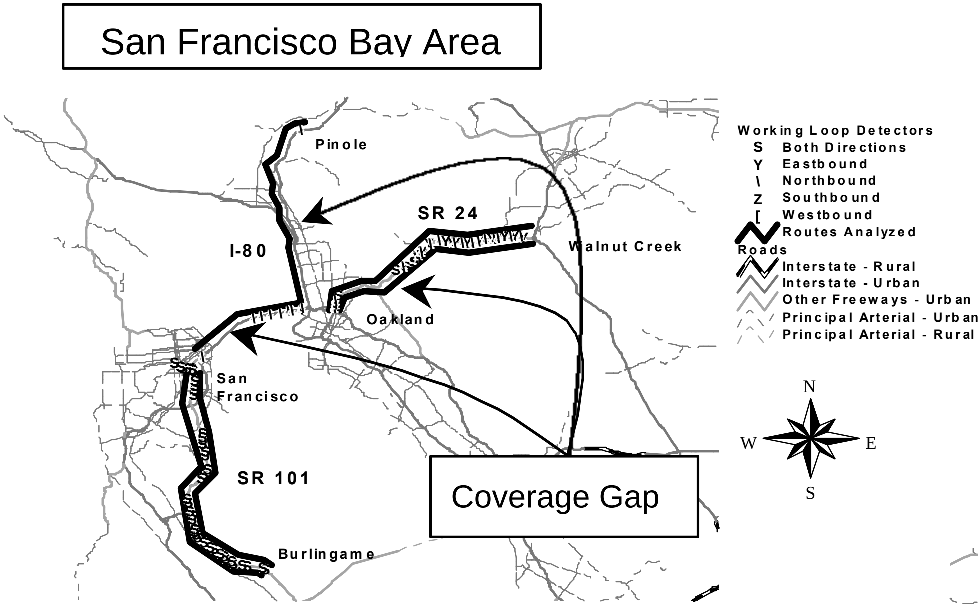
FROM THE DATA COLLECTED, RELIABILITY INDICATORS WERE DEVELOPED FOR SEVERAL FREEWAY SEGMENTS IN THE SAN FRANCISCO BAY AREA, SAN DIEGO AND IN ORANGE COUNTY

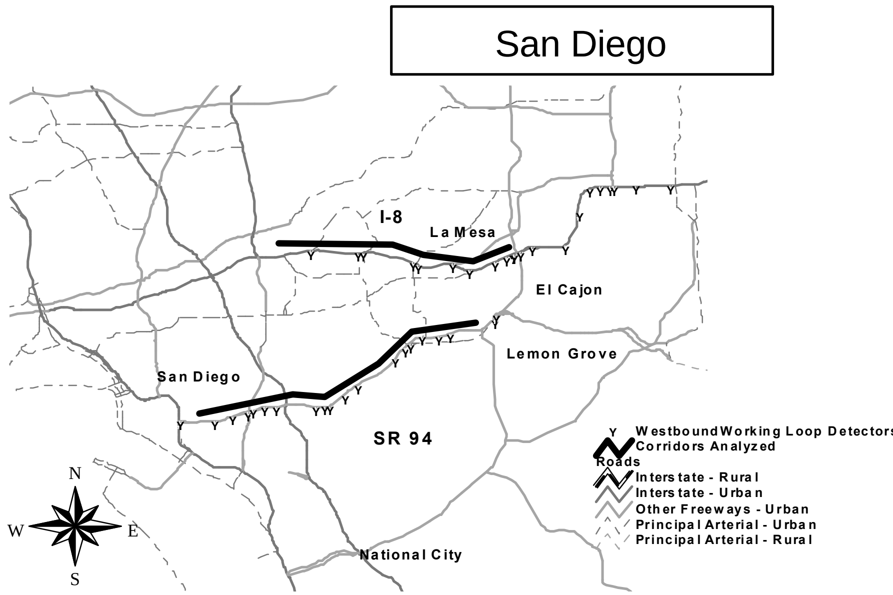
- In the San Francisco Bay Area (District 4) the analyzed freeways include:
  - SR-24 between the Caldecott Tunnel in Oakland and Walnut Creek (I-680)
  - SR-101 from Burlingame just south of the San Francisco International Airport to downtown San Francisco
  - I-80 from Pinole near Appian Way to downtown San Francisco

- In San Diego (District 11) the following segments were analyzed:
  - I-8 from I-15 in San Diego to La Mesa at SR-125
  - SR-94 from near downtown San Diego to Emerald Hills at SR-94/SR-125 interchange

- In Orange County (District 12), the following segments were analyzed:
  - SR-22 from Tustin to Garden Grove
  - I-405 from Harbor Blvd. to Warner Road

Segments Processed in San Francisco and San Diego





RELIABILITY IN THE SAN FRANCISCO BAY AREA VARIED BY FREEWAY SEGMENT, RANGING FROM ONE PERCENT TO 20 PERCENT

- I-80 Westbound from Appian Way in Pinole to downtown San Francisco (6th Street) showed the highest variability at up to 20 percent during the 6:30 to 7:00 PM commute period. This is still ½ of the variability experienced in the AM peak direction of I-405 in Los Angeles that was tested in Phase I

  This segment also showed the highest delay of any segment under analysis in the Bay Area with over 15 minutes of delay experienced during the 8:00 to 8:30 AM period. Interestingly, during the 7:00 to 7:30 AM period the average delay was 12½ minutes, but the variability was only eight (8) percent compared to 14 percent during the 8:00-8:30 AM period

- No other freeway segment analyzed in the Bay Area (SR-24, SR-101) experienced the same levels of delay, although both of these routes showed similar variability along the peak commute direction as the other Bay Area freeways examined. The results for these two freeways are shown in the appendix of this section

Results for the San Francisco Bay Area
I-80 Westbound Pinole to San Francisco

Westbound
Pinole (Appian Way) to San Francisco (4th Street)
Distance = 7.60 Miles

		MOBILITY		RELIABILITY	
	Time of Day	Average Travel Time (Minutes)	Average Delay (Minutes)	Standard Deviation (Minutes)	Percent Variation
AM	6:00-6:30 AM	12.4	5.3	1.1	9%
AM	6:30-7:00 AM	13.3	6.3	1.9	14%
AM	7:00-7:30 AM	19.7	12.7	1.6	8%
AM	7:30-8:00 AM	22.0	14.9	2.6	12%
AM	8:00-8:30 AM	22.3	15.3	3.0	14%
AM	8:30-9:00 AM	18.9	11.8	1.8	10%
PM	4:00-4:30 PM	14.8	7.8	0.2	2%
PM	4:30-5:00 PM	16.5	9.5	1.7	10%
PM	5:00-5:30 PM	17.8	10.8	1.6	9%
PM	5:30-6:00 PM	14.0	6.9	0.6	4%
PM	6:00-6:30 PM	15.9	8.9	2.7	17%
PM	6:30-7:00 PM	17.8	10.8	3.5	20%

IN SAN DIEGO, TRAVEL TIME VARIABILITY RANGED BETWEEN FIVE AND 15 PERCENT ON THE SEGMENTS ANALYZED

- Two freeways (I-8 and SR-94) were analyzed for the AM period with both experiencing similar levels of delay

- SR-94 was less reliable than I-8, especially before 6:30 AM when the variability was nearly double the variability on I-8 (9 percent vs. 5 percent). However, this variability is in the range of variability experienced in the Bay Area

- If data were available, analysis could be expanded to the entire length of these freeway segments and perform the same estimation. Both the I-8 and SR-94 routes are the same travel distance from El Cajon to the San Diego International Airport. However, a person traveling to the airport might take one route over the other if they determined that the predictability of travel time over one freeway were better. In this example, the travel speeds are slightly higher along SR-94 than along I-8. However, the predictability of travel time is better on I-8 than on SR-94. A person in a hurry to catch a flight may choose I-8 since it is more predictable

Results for San Diego

I-8 Westbound
From Waring Rd. to Los Coches Rd.
Distance = 12.9 Miles

		MOBILITY		RELIABILITY	
	Time of Day	Average Travel Time (Minutes)	Average Delay (Minutes)	Standard Deviation (Minutes)	Percent Variation
AM	4:30-5:30 AM	11.7	-	0.6	5%
	5:30-6:30 AM	12.3	0.4	0.6	5%
	6:30-7:30 AM	15.2	3.3	1.5	10%
	7:30-8:30 AM	12.3	0.4	1.2	10%
	8:30-9:30 AM	11.8	-	0.8	7%

SR94 Westbound
From SR125 to 28th St.
Distance = 7.8 Miles

	MOBILITY		RELIABILITY	
Time of Day	Average Travel Time (Minutes)	Average Delay (Minutes)	Standard Deviation (Minutes)	Percent Variation
4:30-5:30 AM	6.9	0	0.6	9%
5:30-6:30 AM	7.5	0.3	0.7	9%
6:30-7:30 AM	9.3	2.1	1.4	15%
7:30-8:30 AM	7.4	0.2	0.8	11%
8:30-9:30 AM	7.0	-	0.6	9%

ORANGE COUNTY SHOWED THE HIGHEST VARIABILITY OF ANY OF THE SEGMENTS ANALYZED

- For the available data, Westbound SR-22 experienced a variability of 50 percent between 4:00 and 4:30 PM and between 5:00 and 5:30 PM. This is higher than the variability shown on I-405 in Los Angeles during Phase I. It should be noted that the Orange County data should be considered a very small sample since only 10 days were available for analysis

- Note that variability on SR-22 westbound ranges between zero and six percent during the AM peak period although no delay is recorded. Eastbound SR-22 shows between five and seven percent variability during the periods experiencing no travel time delay. This means that some variability in travel time will always be experienced even if no delay is being reported. Other segments tested show up to 11 percent variability in travel time even though no delay is being reported (e.g., SR-94 in San Diego)

- Unlike SR-22 westbound, the eastbound direction showed delay during both time periods. This may be due to incidents that were captured during the 10-day period that was sampled

Results for Orange County
SR-22 From Garden Grove to Tustin

Westbound 22
From Tustin Avenue to Valley View Road
Distance = 11.8 Miles

	Time of Day	MOBILITY: Average Travel Time (Minutes)	MOBILITY: Average Delay (Minutes)	RELIABILITY: Standard Deviation (Minutes)	RELIABILITY: Percent Variation
AM	4:00-4:30 AM	11.2	0.5	0.0	0%
AM	4:30-5:00 AM	11.0	-	0.3	3%
AM	5:00-5:30 AM	10.7	-	0.6	5%
AM	5:30-6:00 AM	10.6	-	0.6	6%
AM	6:00-6:30 AM	10.8	-	0.6	5%
AM	6:30-7:00 AM	11.0	-	0.5	4%
AM	7:00-7:30 AM	10.9	-	0.5	5%
AM	7:30-8:00 AM	10.6	-	0.1	1%
AM	8:00-8:30 AM	10.5	-	0.1	1%
AM	8:30-9:00 AM	10.4	-	0.1	1%
AM	9:00-9:30 AM	10.5	-	0.3	3%
AM	9:30-10:00 AM	10.8	-	0.6	6%
PM	3:00-3:30 PM	12.0	1.0	1.1	9%
PM	3:30-4:00 PM	13.0	2.0	1.9	14%
PM	4:00-4:30 PM	14.7	4.0	4.6	32%
PM	4:30-5:00 PM	16.9	6.0	8.5	50%
PM	5:00-5:30 PM	18.8	8.0	8.0	42%
PM	5:30-6:00 PM	21.3	10.5	10.5	50%
PM	6:00-6:30 PM	14.5	3.5	2.9	20%
PM	6:30-7:00 PM	12.1	1.0	1.6	13%
PM	7:00-7:30 PM	10.6	-	0.5	5%
PM	7:30-8:00 PM	10.1	-	0.2	2%

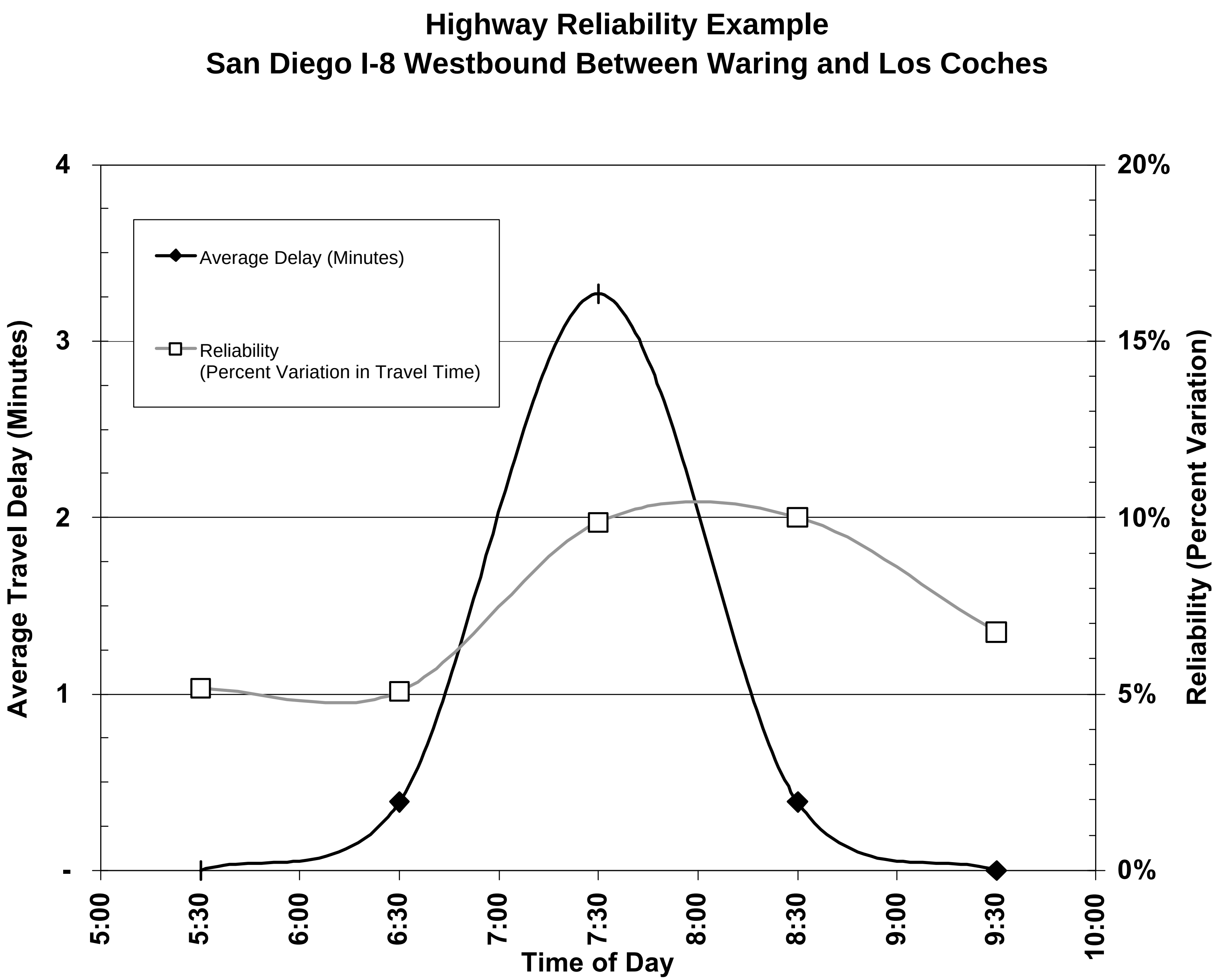
Eastbound 22
From Garden Grove to Tustin
Distance = 10.9 Miles

	Time of Day	MOBILITY: Average Travel Time (Minutes)	MOBILITY: Average Delay (Minutes)	RELIABILITY: Standard Deviation (Minutes)	RELIABILITY: Percent Variation
AM	4:00-4:30 AM	10.2	-	0.7	7%
AM	4:30-5:00 AM	9.8	-	0.5	5%
AM	5:00-5:30 AM	10.0	-	0.6	6%
AM	5:30-6:00 AM	9.9	-	0.7	7%
AM	6:00-6:30 AM	10.3	-	0.7	6%
AM	6:30-7:00 AM	13.4	3.5	1.4	10%
AM	7:00-7:30 AM	14.6	4.5	2.1	14%
AM	7:30-8:00 AM	17.7	7.5	2.6	15%
AM	8:00-8:30 AM	15.7	5.5	2.4	15%
AM	8:30-9:00 AM	13.7	3.5	2.0	15%
AM	9:00-9:30 AM	10.8	0.5	1.5	14%
AM	9:30-10:00 AM	9.9	-	0.7	7%
PM	3:00-3:30 PM	14.1	4.0	3.7	26%
PM	3:30-4:00 PM	13.4	3.5	3.4	26%
PM	4:00-4:30 PM	12.6	2.5	3.2	25%
PM	4:30-5:00 PM	11.6	1.5	2.7	23%
PM	5:00-5:30 PM	12.6	2.5	2.6	20%
PM	5:30-6:00 PM	13.9	4.0	3.4	24%
PM	6:00-6:30 PM	11.4	1.5	2.0	18%
PM	6:30-7:00 PM	10.3	0.5	1.0	10%
PM	7:00-7:30 PM	9.9	-	0.6	6%
PM	7:30-8:00 PM	9.5	-	0.6	6%

THIS INFORMATION CAN BE USED TO PROVIDE COMMUTERS WITH ALTERNATIVES ABOUT TRAVEL TIMES

- In the example from I-8 in San Diego, a person traveling along this segment just after 8:00 AM may experience around two (2) minutes of delay with a possible variation in travel time of 10 percent or more. The same person traveling between 6:30 and 7:00 AM experiences the same delay, but a with only around a six (6) percent variability in travel time

- Variability can also be expressed as probabilities. During a typical month, for example, the user can estimate many days he or she might experience travel times more than the average



Highway Reliability Example
San Diego I-8 Westbound Between Waring and Los Coches
Average Delay (Minutes)
Reliability
(Percent Variation in Travel Time)
Average Travel Delay (Minutes)
Reliability (Percent Variation)
4
3
2
1
-
20%
15%
10%
5%
0%
5:00
5:30
6:00
6:30
7:00
7:30
8:00
8:30
9:00
9:30
10:00
Time of Day

DATA FROM LOOP DETECTORS CAN BE USED TO ESTIMATE INDICATORS OF MOBILITY AND RELIABILITY

- Where available, automatic detection devices such as loop detectors provide speed and volume information that can be translated into travel time, delay and reliability

- There are some coverage gaps in urban areas and loops do not cover the entire state. Caltrans is working to overcome reliability issues

- From this analysis, Booz·Allen finds that highway reliability varies by segment. There are several questions that remain to be answered:

  – Do segments serve different profiles of customers (e.g., commuters)? If yes, how do these different profiles relate to variability?
  – Is ramp metering a factor in these differences?
  – What role do truck volumes and incidents play in variability?
  – What are the impacts of terrain and road conditions on reliability?

- Answering these questions would help Caltrans determine how transportation investments designed to improve reliability could affect different travel markets and routes. Identification of travel markets would help identify which improvements would produce the economic or social benefits to California

APPENDIX

SAN FRANCISCO BAY AREA SR-101 RESULTS

Northbound
Burlingame (Anza Rd.) to San Francisco (25th St.)
Distance = 13.7 Miles

		MOBILITY		RELIABILITY	
	Time of Day	Average Travel Time (Minutes)	Average Delay (Minutes)	Standard Deviation (Minutes)	Percent Variation
AM	6:00-6:30 AM	12.4	-	0.1	1%
	6:30-7:00 AM	12.7	0.1	0.2	1%
	7:00-7:30 AM	13.2	0.6	1.2	9%
	7:30-8:00 AM	14.1	1.5	0.6	4%
	8:00-8:30 AM	14.2	1.6	0.7	5%
	8:30-9:00 AM	14.4	1.8	0.9	6%
PM	4:00-4:30 PM	14.3	1.7	1.6	11%
	4:30-5:00 PM	14.5	1.9	1.5	10%
	5:00-5:30 PM	15.1	2.5	1.6	10%
	5:30-6:00 PM	16.2	3.5	2.1	13%
	6:00-6:30 PM	16.4	3.8	2.4	15%
	6:30-7:00 PM	16.2	3.6	2.5	15%

Southbound
From San Francisco (I-80) to Burlingame (Anza Rd.)
Distance = 15.1 Miles

	MOBILITY		RELIABILITY	
Time of Day	Average Travel Time (Minutes)	Average Delay (Minutes)	Standard Deviation (Minutes)	Percent Variation
6:00-6:30 AM	14.5	0.5	0.2	2%
6:30-7:00 AM	14.8	0.9	0.1	1%
7:00-7:30 AM	16.0	2.1	1.0	6%
7:30-8:00 AM	20.1	6.1	2.1	10%
8:00-8:30 AM	20.8	6.8	2.1	10%
8:30-9:00 AM	19.8	5.8	3.1	16%
4:00-4:30 PM	17.1	3.1	2.6	15%
4:30-5:00 PM	15.9	1.9	1.4	9%
5:00-5:30 PM	15.6	1.6	1.3	8%
5:30-6:00 PM	15.7	1.7	1.1	7%
6:00-6:30 PM	15.4	1.5	1.1	7%
6:30-7:00 PM	15.1	1.2	0.8	5%

SAN FRANCISCO BAY AREA SR-24 RESULTS

Eastbound
Oakland (Caldecott Tun.) to Walnut Creek (I-680)
Distance = 11.1 Miles

	Time of Day	MOBILITY: Average Travel Time (Minutes)	MOBILITY: Average Delay (Minutes)	RELIABILITY: Standard Deviation (Minutes)	RELIABILITY: Percent Variation
AM	6:00-6:30 AM	10.2	-	0.2	2%
AM	6:30-7:00 AM	10.3	0.0	0.1	1%
AM	7:00-7:30 AM	10.3	0.0	0.1	1%
AM	7:30-8:00 AM	10.5	0.2	0.1	1%
AM	8:00-8:30 AM	10.6	0.3	0.1	1%
AM	8:30-9:00 AM	10.5	0.2	0.1	1%
PM	4:00-4:30 PM	11.8	1.6	1.9	16%
PM	4:30-5:00 PM	11.5	1.2	1.0	9%
PM	5:00-5:30 PM	11.0	0.7	0.4	4%
PM	5:30-6:00 PM	11.1	0.8	0.5	4%
PM	6:00-6:30 PM	10.9	0.6	0.5	5%
PM	6:30-7:00 PM	10.7	0.4	0.1	1%

Westbound
Lafayette (Pleasant Hill Rd.) to Oakland (Caldecott Tun.)
Distance = 10.7 Miles

	Time of Day	MOBILITY: Average Travel Time (Minutes)	MOBILITY: Average Delay (Minutes)	RELIABILITY: Standard Deviation (Minutes)	RELIABILITY: Percent Variation
AM	6:00-6:30 AM	11.3	1.4	0.8	7%
AM	6:30-7:00 AM	11.8	1.8	0.7	6%
AM	7:00-7:30 AM	13.2	3.3	1.4	11%
AM	7:30-8:00 AM	14.7	4.8	1.7	11%
AM	8:00-8:30 AM	14.8	4.9	2.3	15%
AM	8:30-9:00 AM	14.0	4.1	2.1	15%
PM	4:00-4:30 PM	12.2	2.3	0.4	3%
PM	4:30-5:00 PM	12.2	2.3	0.4	3%
PM	5:00-5:30 PM	12.3	2.4	0.3	2%
PM	5:30-6:00 PM	12.3	2.4	0.3	2%
PM	6:00-6:30 PM	12.4	2.4	0.2	2%
PM	6:30-7:00 PM	12.2	2.3	0.4	4%

ORANGE COUNTY I-405 RESULTS

Northbound 405
From Harbor Blvd. to Warner Rd.
Distance = 5.9 Miles

		MOBILITY		RELIABILITY	
	Time of Day	Average Travel Time (Minutes)	Average Delay (Minutes)	Standard Deviation (Minutes)	Percent Variation
AM	4:00-4:30 AM	6.0	0.5	0.3	4%
	4:30-5:00 AM	5.7	-	0.1	3%
	5:00-5:30 AM	5.4	-	0.1	2%
	5:30-6:00 AM	5.5	-	0.1	3%
	6:00-6:30 AM	5.5	-	0.1	2%
	6:30-7:00 AM	5.5	-	0.1	1%
	7:00-7:30 AM	5.5	-	0.0	1%
	7:30-8:00 AM	5.5	-	0.1	2%
	8:00-8:30 AM	5.6	-	0.2	3%
	8:30-9:00 AM	5.8	0.5	0.4	8%
	9:00-9:30 AM	5.6	-	0.1	2%
	9:30-10:00 AM	5.7	-	0.1	1%
PM	3:00-3:30 PM	6.8	1.5	2.0	29%
	3:30-4:00 PM	8.1	2.5		30%
	4:00-4:30 PM	10.2	4.5	2.2	21%
	4:30-5:00 PM	11.0	5.5	3.6	33%
	5:00-5:30 PM	12.0	6.5	3.0	25%
	5:30-6:00 PM	13.3	8.0	2.4	18%
	6:00-6:30 PM	12.1	6.5	2.8	23%
	6:30-7:00 PM	9.8	4.5	3.0	31%
	7:00-7:30 PM	6.0	0.5	1.1	19%
	7:30-8:00 PM	5.4	-	0.1	2%

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Applicability of Indicators to Transit

Technical Memorandum

Booz·Allen & Hamilton Inc.
June 30, 1999

TABLE OF CONTENTS

BOOZ·ALLEN & HAMILTON ADDRESSED THE APPLICABILITY OF PERFORMANCE INDICATORS TO TRANSIT, FOCUSING ON THREE OUTCOMES: MOBILITY & ACCESSIBILITY, RELIABILITY, AND SAFETY & SECURITY

- The methodology used to develop recommendations was multi-pronged and included the following components:

  - Detailed transit industry interviews within California
  - Regular meetings with project advisory committee
  - Indicator analysis and data availability evaluation
  - Development of final indicator composition for each outcome

- The principal findings are that it is feasible to apply system performance indicators to transit by using the same indicators identified for the highway mode (e.g., travel time and lost time to measure mobility)

- As anticipated, the main challenges in applying these indicators on a system-wide basis include the number of transit systems to monitor, availability of data and processing time in some cases. These can all be mitigated through proper planning

- The agencies interviewed were open to providing Caltrans with the data needed for performance indicator development and analysis

DETAILED CONCLUSIONS AND RECOMMENDATIONS ARE PROVIDED ON THE NEXT PAGES

DETAILED FINDINGS AND RECOMMENDATIONS FOR MOBILITY & ACCESSIBILITY…

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	RECOMMENDATIONS
Mobility & Accessibility	Travel Time	• Travel time can be derived from transit agency schedules • Some transit agencies do not publish schedules, though travel time can be calculated using average speeds and distance traveled	Use travel time as the first indicator for transit mobility	• Use schedules as basis for determining travel time • When schedules are not available, rely on average speeds to calculate travel time • Develop a baseline travel time for region/State to monitor, forecast and report travel time for improvements
Mobility & Accessibility	Delay (Lost Time)	• Delay (lost time or recurrent delay) can be calculated based on the difference between actual and optimal travel times • Optimal travel times are based on free-flow (i.e., uncongested speeds)	Use delay as the second indicator for transit mobility	• Use the schedules and optimal travel time calculations to determine delay for transit routes • Develop a baseline lost time for region/State to monitor, forecast and report delay for improvements

DETAILED FINDINGS AND RECOMMENDATIONS FOR ACCESSIBILITY AND RELIABILITY…

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	RECOMMENDATIONS
Mobility & Accessibility	Accessibility to Transit System	• Applications exist for some parts of the State to readily link demographic data to transit system on a Geographic Information System (GIS) • 2000 Census data will be available for analysis next year	Use accessibility to the transit system as indicator for accessibility	• Refine demographic fields to include in accessibility • Work with regions to develop consistent GIS interface and populate census data state-wide • Develop baseline accessibility for region/State to monitor, forecast and report accessibility for improvements
Reliability	Standard Deviation of Travel Time Variability	• Reliability of travel time can be calculated for non-recurrent delay • Transit agencies generally don't compute reliability of travel time but the data is available to support the analysis	Use the standard deviation of travel time variability in excess of the schedule as indicator for reliability	• Develop baseline reliability for region/State to monitor, forecast and report reliability for improvements

DETAILED FINDINGS AND RECOMMENDATIONS FOR SAFETY AND SECURITY…

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	RECOMMENDATIONS
Safety / Security	Safety Rates	• Safety rates are routinely reported by transit agencies • Safety measures themselves differ by transit operator	Use safety rates or number of accidents as indicator for safety and security	• Use consistent units for safety rates • Develop baseline safety for region/State to monitor, forecast and report safety for improvements
Safety / Security	Crime Events	• Crime events are collected by transit agencies or associated police departments • There is no equivalent source of data for highway auto crime events	Use security events or rates as indicator for safety and security	• If rates are selected, use consistent units • Develop baseline security for region/State to monitor, forecast and report security for improvements

I. INTRODUCTION

THIS TECHNICAL MEMORANDUM PROVIDES A SUMMARY OF THE APPLICABILITY OF THE INDICATORS IDENTIFIED IN PHASE I TO THE TRANSIT MODES

- Research and testing of indicator applicability to transit and inter-city rail to three primary outcomes:
  - Mobility
  - Reliability
  - Safety
- Ease of data gathering and calculation:
  - Existence of the data
  - Availability of the data
  - Ease of data use

THIS PROJECT CONSISTED OF FOUR MAIN PHASES

- Peer agency selection – selecting a representative set of agencies for interview purposes
  - Modal mix
  - Geographic representation
  - Contact and protocol
- Discussion framework – how to interpret the applicability of different indicators to the transit modes
- Fact finding report on routinely collected data
  - Mobility/accessibility
  - Reliability
  - Safety and security
- Conclusions

IN CONCERT WITH THE SYSTEM MEASURES WORKING GROUP, BOOZ·ALLEN SELECTED A BALANCED SET OF TRANSIT AND INTERCITY RAIL INDUSTRY ORGANIZATIONS FOR THE STUDY

THE SET REPRESENTS TWO MORE OPERATORS THAN SPECIFIED BY THE ORIGINAL CONTRACT

AGENCIES INTERVIEWED

Bay Area Rapid Transit (BART)
AC Transit
Amtrak
Metrolink
San Diego Trolley
San Diego Transit
San Diego Association of Governments (SANDAG)

CONTACTS WITH THE AGENCIES WERE MADE THROUGH A CAREFULLY CRAFTED PROTOCOL

- Booz·Allen identified and contacted specific individuals able to contribute relevant agency information for each area of interest, and explained the nature of the study. In some cases the team discovered that additional organizations, such as a Metropolitan Planning Organization (MPO), warranted individual contact

- Caltrans headquarters sent detailed cover letters to the agency heads detailing the nature of the study, specifically naming the individuals to be contacted by Booz·Allen. In addition, copies of the Phase I, 1998 California Transportation Plan: Transportation System Performance Measures report were mailed to each recipient

- Booz·Allen scheduled and interviewed each agency on-site (some agencies required multiple interviews; e.g., director of planning and director of safety)

II. DISCUSSION FRAMEWORK

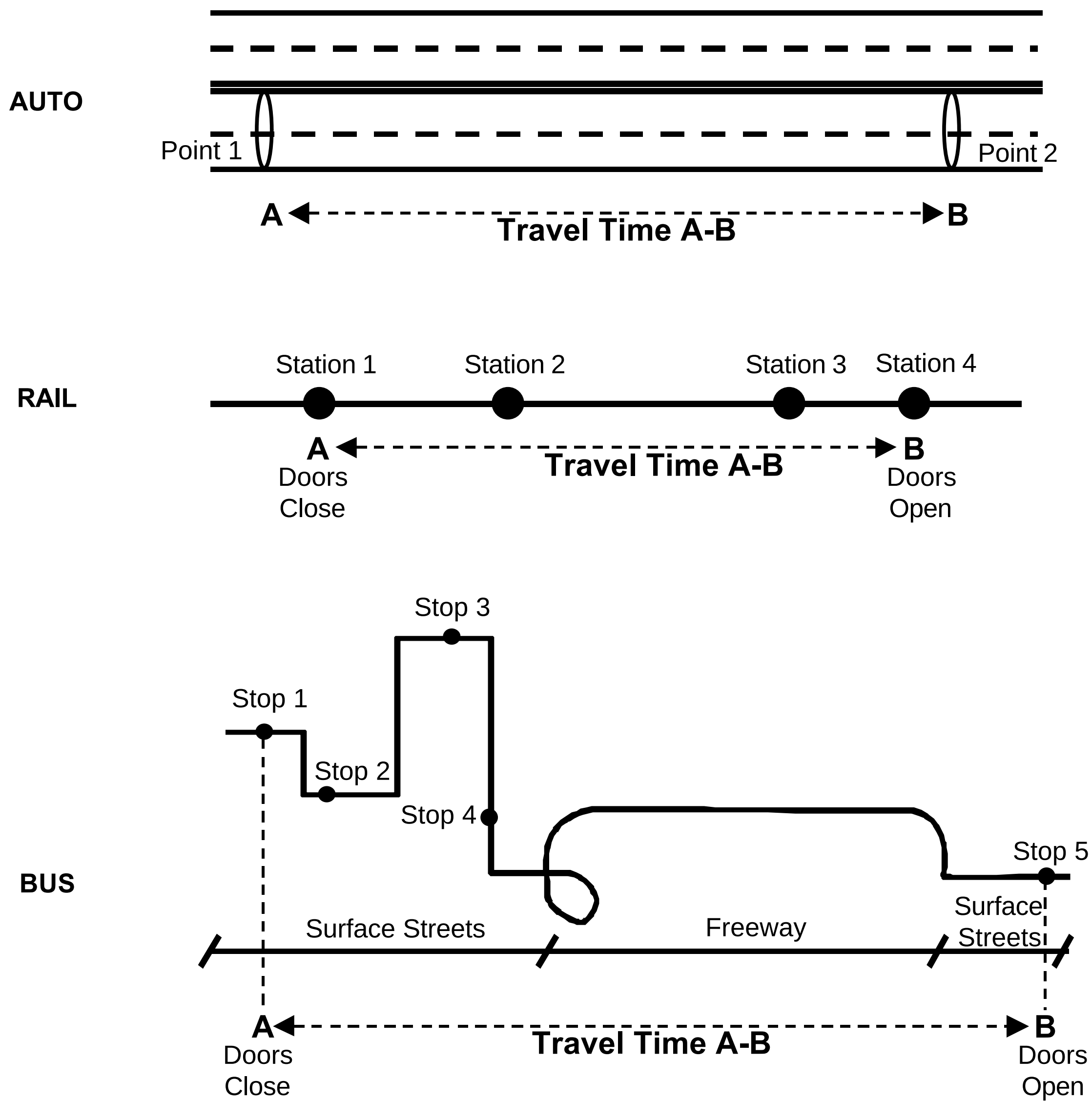
THE FOLLOWING DISCUSSION FRAMEWORK EXPLORES INDICATORS FOR THE MOBILITY & ACCESSIBILITY, RELIABILITY AND SAFETY OUTCOMES

- Mobility & Accessibility Outcome
  - Travel Time
  - Delay
  - Accessibility to Desired Facilities
  - Accessibility to Transportation Network
- Reliability Outcome
  - Variability of Travel Time
- Safety & Security Outcome
  - Accident Rates
  - Crime Rates

TRAVEL TIME IS CONCEPTUALLY THE MOST STRAIGHTFORWARD OF ALL MOBILITY INDICATORS

- Travel time represents the time to travel from A to B regardless of mode
- Where available, schedules provide the customer with estimated travel times
- For performance measurement, travel time will need to be aggregated at different system component levels as appropriate (route, corridor, region and state)
- Travel time indicators should, to the extent possible, focus on the user perspective and address both monitoring and forecasting

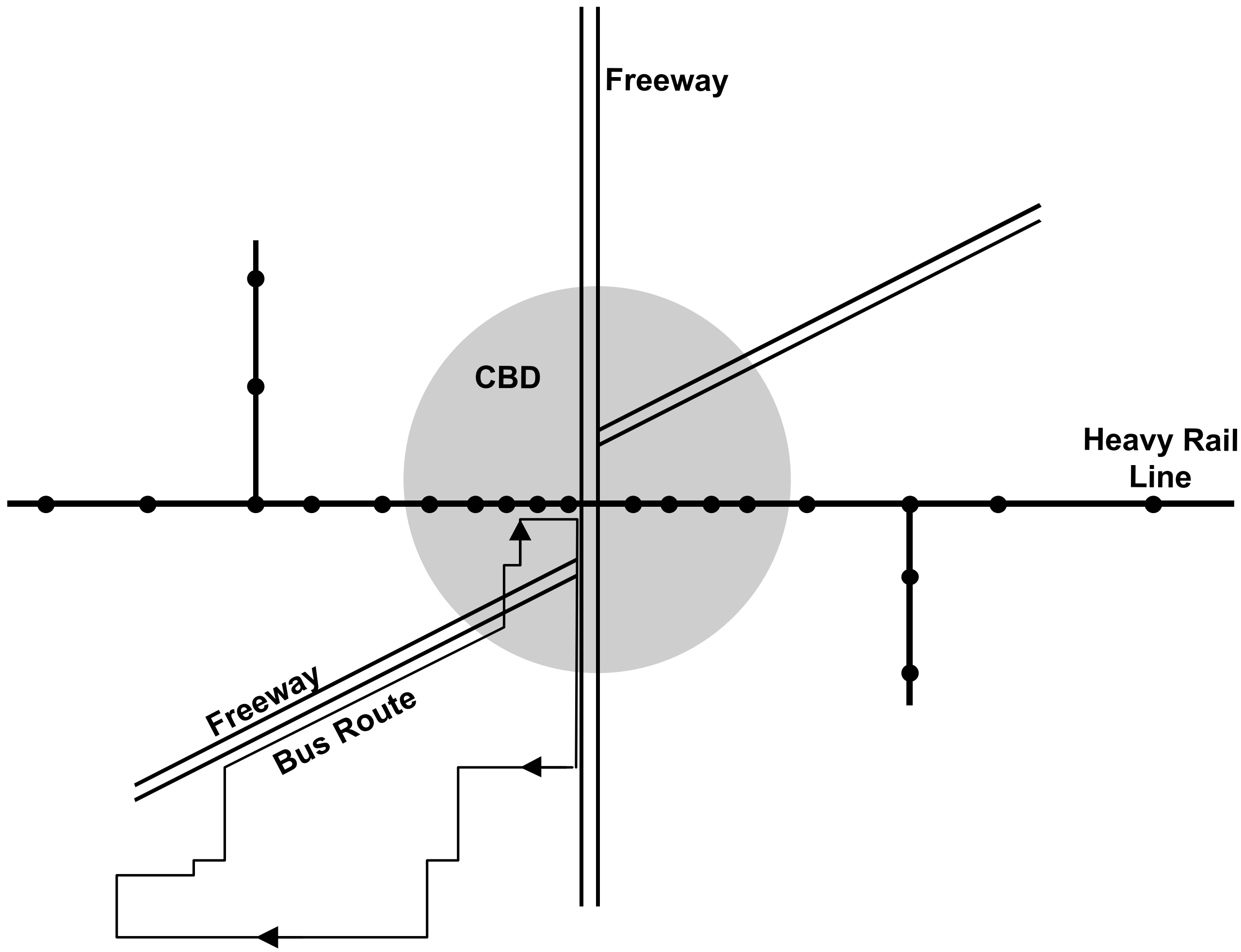
TRAVEL TIME ILLUSTRATION



MOBILITY INDICATORS TO BE TESTED MUST TAKE INTO ACCOUNT RIGHT OF WAY DIFFERENCES

MODE	DEDICATED ROW		SHARED ROW	
	Single Guideway User	Shared Guideway	Surface Street/Arterial	Freeway
Auto, truck			✓	✓
Bus			✓	✓
Light rail, street			✓	
Light rail, dedicated	✓			
Light rail, mixed	✓		✓	
Heavy/commuter rail	✓			
Inter-city rail		✓		

RIGHT OF WAY ILLUSTRATION



FOR TRANSIT, DELAY OCCURS DUE TO BOTH EXTERNAL AND INTERNAL FACTORS

- External factors include street congestion, passenger-related disruptions, and miscellaneous external delay causing events, such as the weather or vandalism

- Internal factors include inadequate physical plant maintenance, operations disruptions, mechanical problems, as well as operator or crew-caused delays

- The delay indicator must fairly address modal differences:

  - Right of Way - for instance, with a dedicated ROW there is no street congestion. Some light rail systems operate in mixed ROW environments and therefore do experience some auto congestion

  - Variable number of stops, such as a bus route, where the number of stops is entirely dependent upon passenger demand (e.g., sometimes there are many stops; other times, none)

INPUTS TO SCHEDULE (RAIL EXAMPLE)

PUBLISHED SCHEDULE	"OPTIMAL" TRAVEL TIME	POTENTIAL CAUSES OF DELAY
Dwells Accelerations Average travel speeds Decelerations Padding to schedule	Dwells Accelerations Maximum authorized travel speeds Decelerations	Mechanical Operations related: - routing - traffic Passenger related: - groups - disabled/elderly - other Physical plant Street congestion Miscellaneous - Operator - service failures - crew related - other Miscellaneous - External - weather/environment - vandalism - other

ONE WAY TO ADDRESS DELAY FOR BUS RUN TIMES IS TO CONSIDER THE DIFFERENCE BETWEEN THE AVERAGE SCHEDULE TIME AND THE "OPTIMAL" TRAVEL TIME

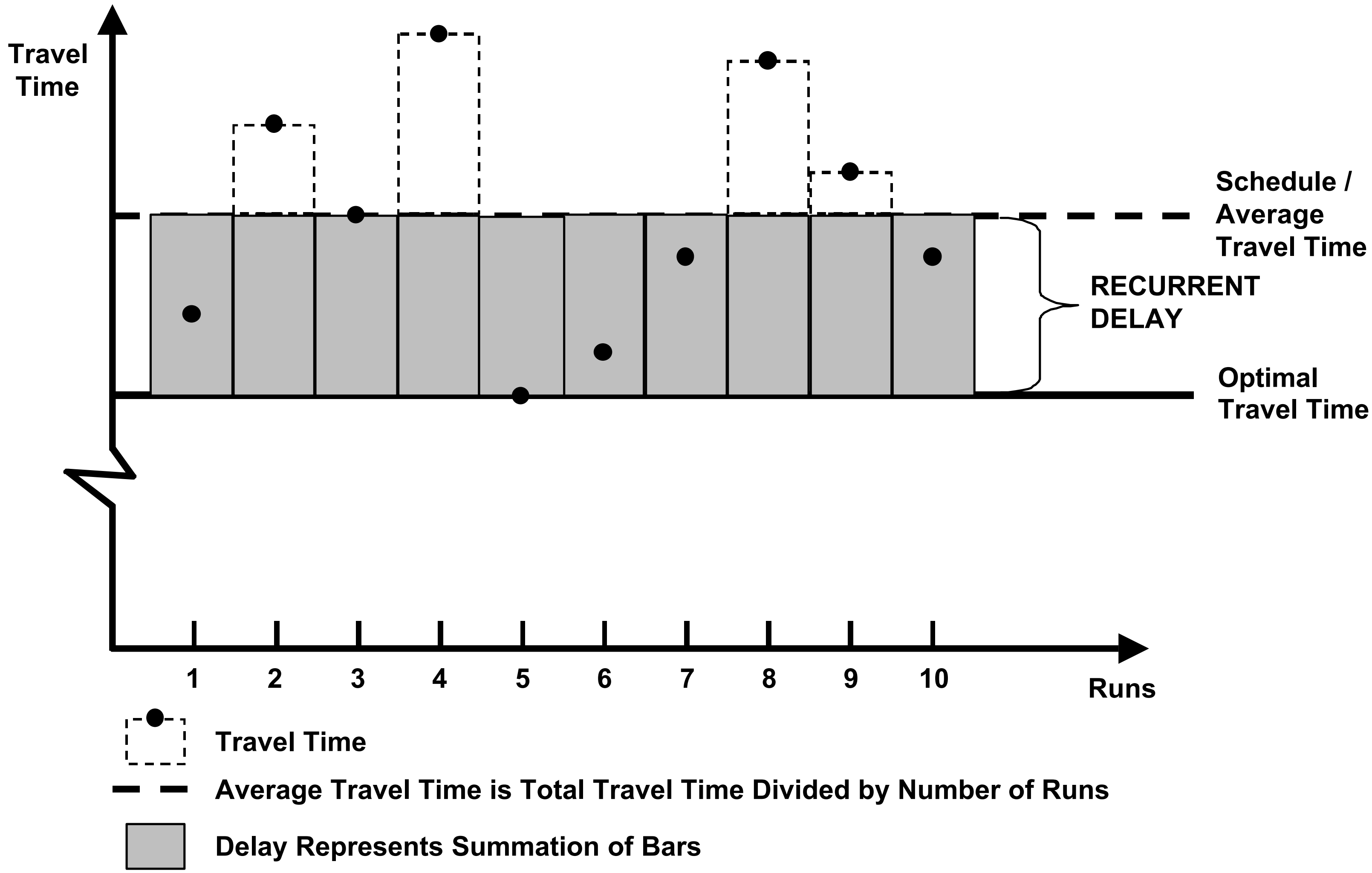
- Step 1: Compute optimal travel time for bus route and compare to schedule

> **Example**
> Route length: 20 miles
> Percent of service on local streets: 90%
> Optimal local speed: 15 mph
>
> Percent highway service: 10%
> Optimal highway speed: 65 mph
>
> Weighted average optimal speed = (0.90x15)+(0.10x65) = 20 mph
>
> Optimal travel time: 60 minutes
> Schedule: 75 minutes
> (Average Delay = 75 min. – 60 min. = 15 minutes)

- Step 2: Aggregate total average delay based on level desired (line, operator, period, region). See above

RAIL CAN BE APPROACHED IN THE SAME MANNER

RECURRENT DELAY CALCULATION



Note: Average travel time assumes that transit agencies take recurrent delay when cutting schedule

ACCESSIBILITY TO CERTAIN LOCATIONS AND TO THE TRANSPORTATION SYSTEM REPRESENTS AN IMPORTANT RESEARCH AND MARKETING ELEMENT FOR TRANSIT SYSTEMS

- The indicators address the ease of access for individuals to either important destinations or to the transportation system:

  - Accessibility to desired locations
  - Accessibility to the transportation system

- Desired locations have yet to be clearly defined in the context of accessibility. Accessibility to locations can be analyzed when regions and the State agree on threshold definitions or listings of specific facilities (e.g., commercial airports or employment centers of a certain size)

- Either way, the best approach is through Geographic Information Systems (GIS), with linkages to solid census data for the region:

  - Through buffer analyses, GIS enables one to determine percentages of people within buffer ranges of specific facilities of interest or transit stations (e.g., 0.3 mile)

  - Potentially beneficial census fields include travel time, mode, age, income level, ethnicity, and car ownership

RELIABILITY OF TRAVEL TIME IS A GOOD CANDIDATE FOR SIMILAR INTERPRETATION IN TRANSIT AND AUTOMOBILE TRAVEL

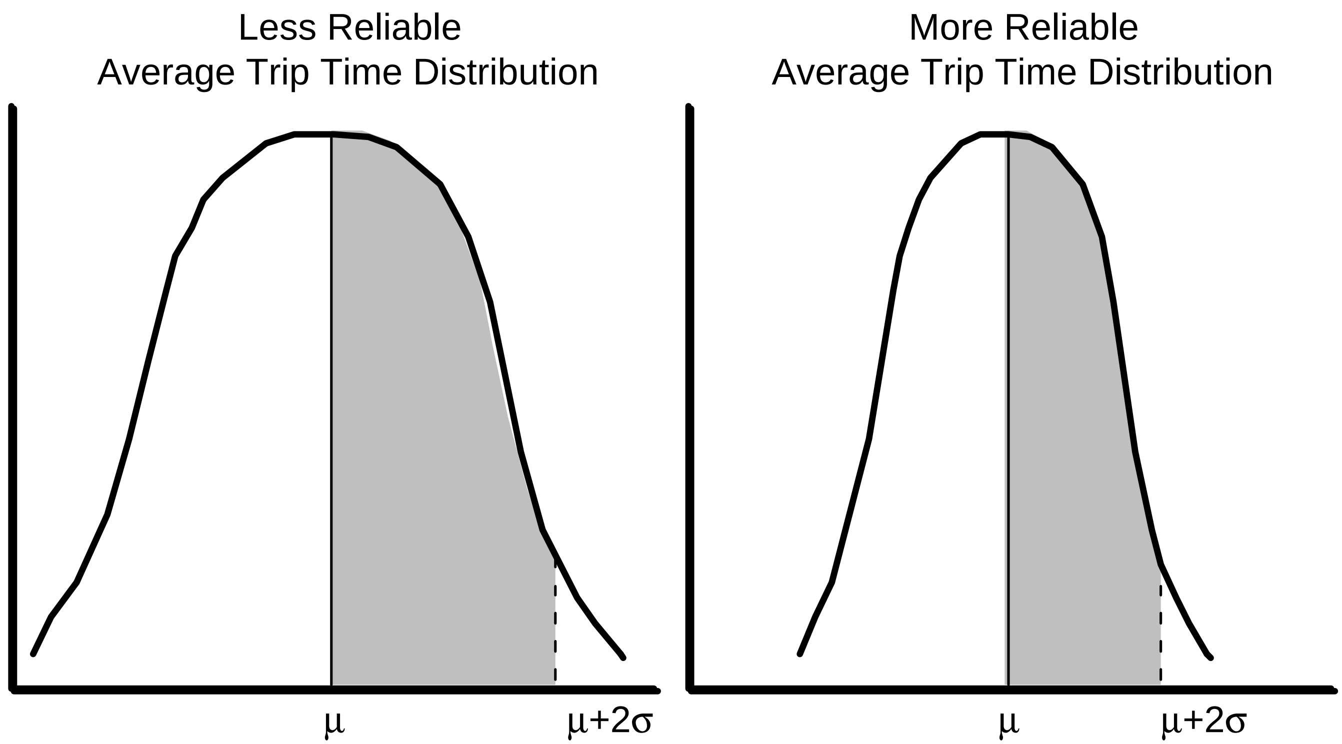
- Reliability is defined as the level of variability in transportation service between anticipated (based on scheduled or normal travel) and actual travel

- Variability is primarily a consequence of non-recurrent delays (i.e., delays not accounted for in the establishment of normal schedules). On the freeways, travel time variability may reflect incidents and the time to manage them. In transit, it may reflect unanticipated breakdown of equipment (e.g., buses, rail cars). Reducing variability is therefore a function of reducing the instances of non-recurrent delays (e.g., through more intensive maintenance practices) and reducing the time it takes to resolve such delays (e.g., through faster and more systematic incident management or preventive measures)

- The monitoring of reliability for transit is more appropriate for congested urban regions than for rural regions where transit frequencies are lower

- The candidate measure for reliability is the variability of the travel time, i.e., the standard deviation of average trip time distribution

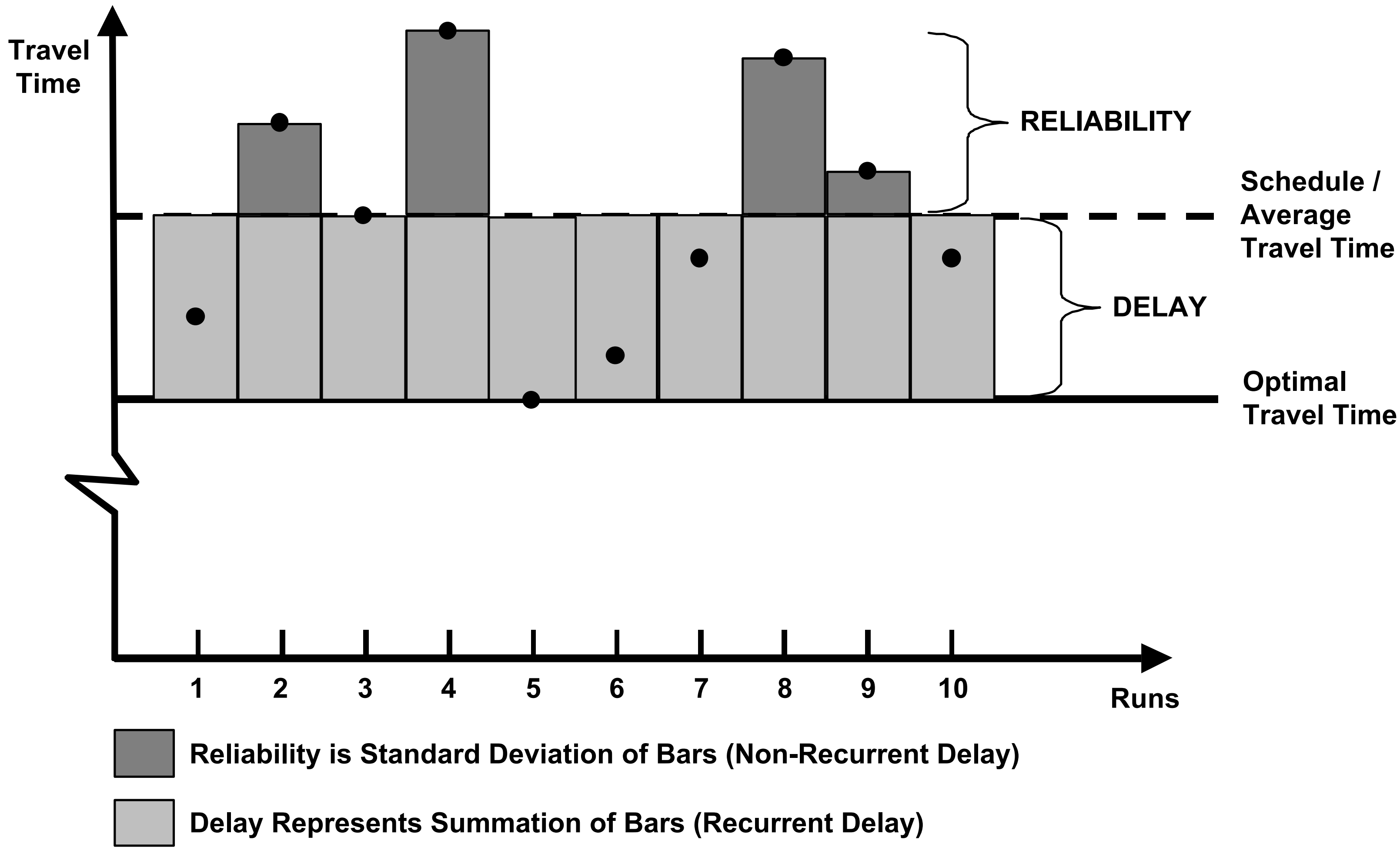
TRAVEL TIME RELIABILITY



μ = Mean

σ = Standard Deviation

NON-RECURRENT DELAY (I.E., BEYOND THE SCHEDULE AND SHOWN IN DARK BARS) WILL BE USED TO COMPUTE TRAVEL TIME RELIABILITY



Step 1 Compute Optimal Travel Time

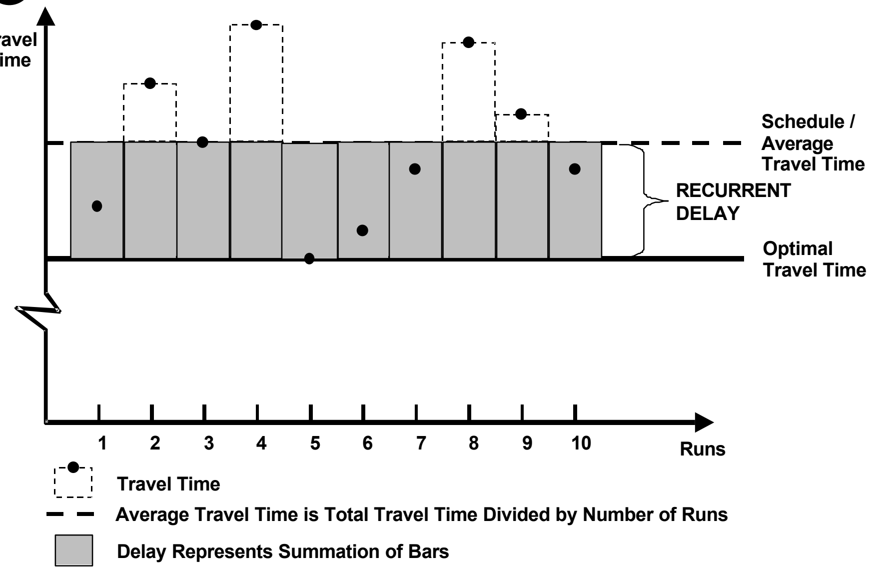
Example
Route length: 20 miles
Percent local service: 90%
Optimal local speed: 15 mph

Percent highway service: 10%
Optimal highway speed: 65 mph

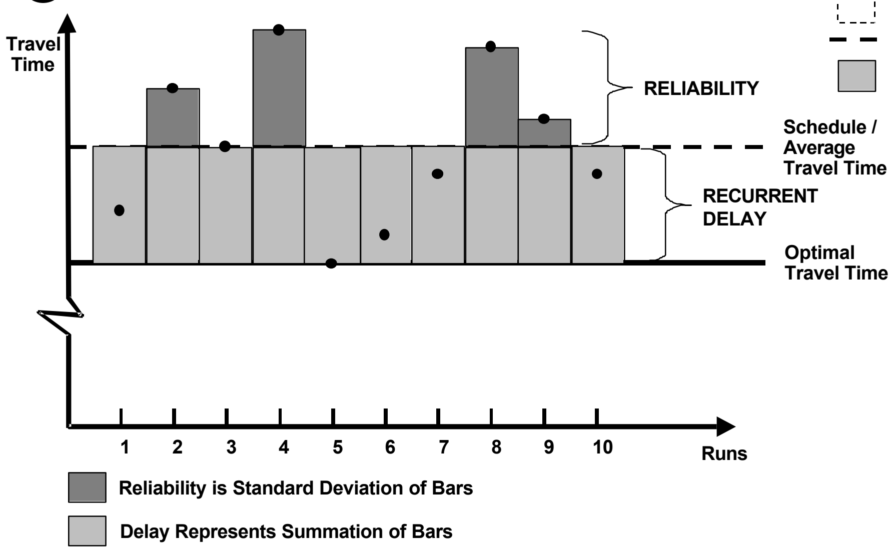
Weighted average optimal speed = (0.90x15)+(0.10x65)
= 20 mph

Schedule: 75 minutes
Optimal travel time: 60 minutes
Delay = 75 min. - 60 min. = 15 minutes

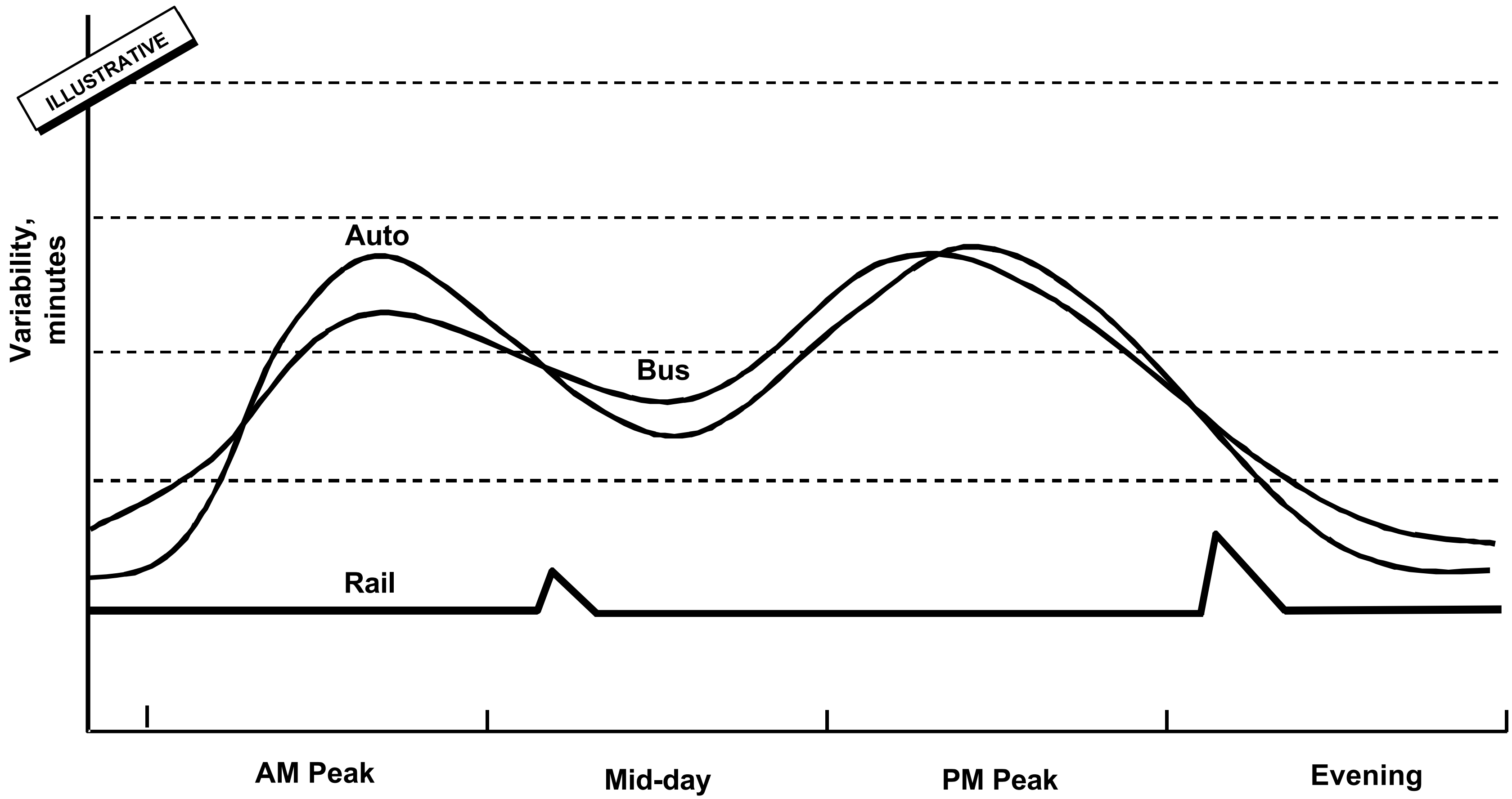
Step 2 Plot Actual Travel Time & Calculate Delay



Step 3 Compute Variability in Travel Time



VARIABILITY IN TRAVEL TIME WILL BE LINKED TO THE MODE CONSIDERED



IN ADDITION TO SAFETY INDICATORS, TRANSIT AGENCIES ALSO COLLECT AND ANALYZE SECURITY INDICATORS

	AUTO	TRANSIT AND INTER-CITY RAIL
SAFETY	Accident rates - fatality accidents - injury accidents - property damage accidents Safety totals - fatalities - injuries	Accident rates - fatality accidents - injury accidents - property damage accidents Safety totals - fatalities - injuries Note: can be separated by stations, vehicles and right of way, employee versus public
SECURITY	Not applicable	Category 1 events: homicide, rape, robbery, assault, etc. Category 2 events: graffiti, vandalism, sexual harassment, etc.

III. ROUTINELY COLLECTED DATA

WITH REGARDS TO MOBILITY AND DELAY, QUESTIONS ASKED TO THE TRANSIT AND INTER-CITY RAIL AGENCIES FOCUSED ON FOUR ELEMENTS

- Route and operations description

- Components to the schedule
  - dwells
  - maximum and average speeds
  - padding to schedule

- Issues related to delay:
  - definition
  - ability to make up time in cases of delay

- On-time performance reports and delay statistics:
  - on-time report
  - delay summary
  - causes of delay
  - storage of data

Operator	BART - Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
Scheduled Travel Time	51 to 73 minutes Most lines approximately 1 hour	40 to 105 minutes
Dwells	35-40 seconds in downtown SF; 10-15 seconds in outlying areas	40 seconds
Speeds	Most trains run at Performance Level 2, which is one notch below maximum authorized speed (PL 1 is 80 mph in Transbay Tube)	FRA requires trains to operate at maximum authorized speed. Top speed is 90 mph in Automatic Track Signal section; 79 mph elsewhere
Accel./ Deceleration	Trains operate at half or full acceleration (3.2 mph/sec)	N/A
Padding	Schedule developed empirically by using percentile of average runs and average dwells, results in approximately 2 to 3 minutes of padding	Recovery time is added to schedule just before last station (5-15% of end-to-end travel time, depending on other traffic on line)
Operations remarks	Computer controls performance characteristics (maximum speed, acceleration, etc.)	Own one right-of-way, have trackage rights on others. Share all tracks with Amtrak and/or freight trains
Average speed	45 mph in outlying areas, 36 mph in CBDs	45 mph (systemwide, including stops)

THE AGENCIES INTERVIEWED INCLUDE RECURRENT DELAY INTO BASELINE SCHEDULE CREATION

Schedule Elements

- Dwells
- Acceleration
- Optimal Travel Time
- Deceleration

- Padding

“Optimal” to “Schedule” Time Expansion

❶ Actual Run Time Average
- San Diego Transit

Padding:

❷ Fixed (e.g. 2 min)
- San Diego Trolley

❸ Percent-Based (e.g. 10%)
- AC Transit, Amtrak

❹ Run Profile-Based (e.g. 85%)
- BART

Baseline Schedule

- Dwells
- Acceleration
- Optimal Travel Time
- Deceleration
- Padding

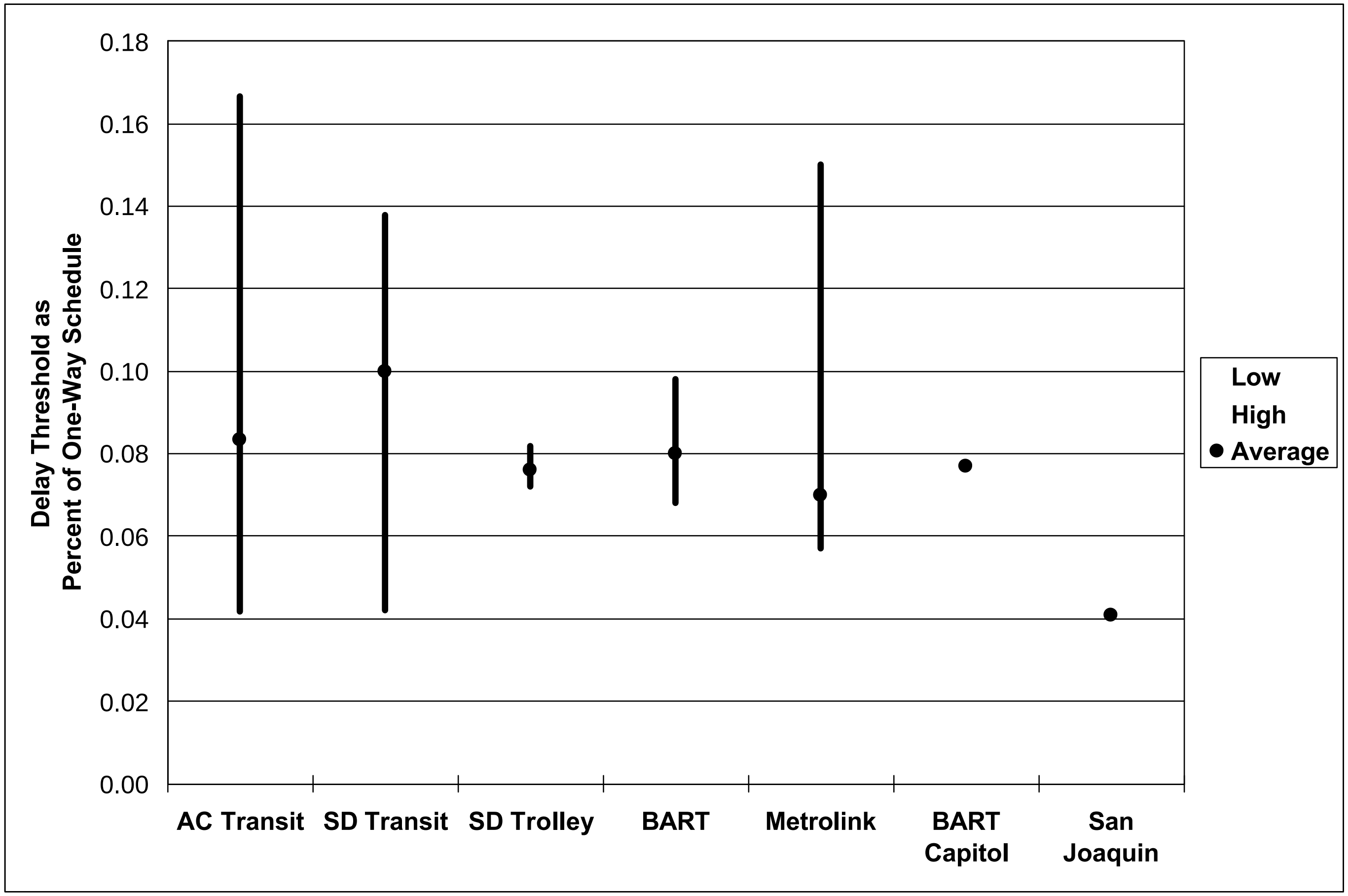
TRANSIT PROPERTIES ALSO TRACK NON-RECURRENT DELAY AND ON-TIME PERFORMANCE VIA A DELAY THRESHOLD

- AC Transit, San Diego Trolley and Transit and BART heavy rail all observe a 5 minute delay threshold. Metrolink classifies runs as late if they are 6 minutes or more at the final destination. Finally, BART and Amtrak use 10 minutes and 15 minutes for the Capitol and San Joaquin routes, respectively

- Typically the driver or operator must call in to dispatch when a delay event arises and ask for guidance

- The ability to make up time for late buses and trains is generally quite limited. Some operators use "skip stop" techniques to save some time. At BART, computers automatically adjust dwells when a train is delayed

DELAY THRESHOLD BY TRANSIT PROPERTY



AMONG THE AGENCIES INTERVIEWED SANDAG AND BART HAVE DRIVEN THE FURTHEST IN TERMS OF THE ACCESSIBILITY INDICATORS ENVISIONED IN THE STUDY – ACCESSIBILITY TO TRANSPORTATION NETWORK AND TO DESIRED LOCATIONS

- The San Diego Association of Governments (SANDAG):
  - publishes top transit trip destinations (e.g., colleges, shopping centers, employment sites) by Transit Analysis Zone (TAZ) for FTA Title 6 certification every three years
  - developed an application to analyze access to the transit system called "View2Transit". The application enables the user to buffer out from transit stops and examine selected census data
- The Bay Area Rapid Transit District (BART):
  - researched catchment area and accessibility range based on combination of customer surveys (e.g., Passenger Profile Survey), ABAG population forecasts, and in-house GIS model
  - conducted surveys at BART parking lots to research home residential locations
  - occasionally conducts focus groups for niche markets (e.g., sport event attendees)
  - analyzes catchment areas around BART stations to comply with FTA Title 6 certification

OTHER AGENCIES INTERVIEWED HAVE BEGUN TO ADDRESS ACCESSIBILITY THROUGH SURVEYS AND INCREASED GIS DEPLOYMENT

- Southern California Regional Rail Authority (Metrolink):
  - conducts on-board surveys (including questions such as "how did you get to the station?"). Previously done annually; considering going to continuous one-on-one on-board surveys
  - Marketing works with employers to identify travel patterns and needs
  - Operating Department works with other transit operators to identify key facilities (e.g., connector service to USC Medical Center area)
- AC Transit:
  - estimates the network provides 90 percent of patrons a bus stop within 0.25 mile walk
  - is using plotting maps provided by MTC, and is currently migrating from MapInfo to ArcView
  - The SatCom 2000 project aims to provide a real time ability to communicate with passengers at key stops and will include 100 percent Automatic Vehicle Locator (AVL) on buses by 2002-2003. SatCom will be fully linked to Trapeze, the scheduling system

FEW AGENCIES TRACK RELIABILITY OF TRAVEL TIME

- On-time performance (listed as a percent by route or by system) is the most common measure
- Virtually all agencies interviewed agreed with the reliability indicator proposed by Caltrans. BART was the exception, recommending using frequencies or histograms instead of the standard deviation
- Travel time data is generally available for light rail, heavy rail, commuter rail and Amtrak. For bus networks, sample data is available covering three to five percent of all trips

SAFETY AND SECURITY REPORTS ARE PRODUCED FOR INTERNAL, STATE, AND FEDERAL REQUIREMENTS

- The properties track many safety and security indicators for internal reasons, including presentations to the Board (e.g., San Diego Trolley)
- For the State level, San Diego Trolley's most complete safety reporting requirements are the Public Utilities Commission
- Safety and Security reporting requirements exist for the Federal Transit Administration (FTA) and Federal Railroad Administration (FRA)

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Safety Reporting Requirements	Report to FTA through National Transit Database	San Diego Trolley is responsible for safety reporting	Most complete reporting requirements are to the Public Utilities Commission (PUC) FTA requirements Internal requirements for Board
Safety Reports	National Transit Database (Section 15) Monthly Accident Summary (internal document): Collisions description, accidents per 100,000 bus miles	**Risk Activity Report** (monthly) - includes: Accidents (collision, non-collision, total, injury/damage) Breaks out preventable versus non-preventable accidents and presents ratios (e.g., per 100k miles)	**Risk Activity Report** (monthly) - includes: Accidents (collision, non-collision, total, injury/damage) Breaks out preventable versus non-preventable accidents and presents ratios (e.g., per 100k miles) **Safety Accident Report** (annual summary)
Safety Indicators	- Accidents per 100,000 buses miles (69 different accident categories)	Presented to Board: Accidents per 100,000 bus miles (aggregate, difference with previous month and % variance)	- LRV/auto accidents by line - LRV/pedestrian accidents by line - total accidents - personal injuries by type - medical emergencies - employee emergencies

SEPARATELY FROM AMTRAK, THE FEDERAL RAILROAD ADMINISTRATION, OFFICE OF SAFETY ANALYSIS, ROUTINELY TRACKS SIX SAFETY INDICATORS

- Total accident/incident rate: reported events x 1,000,000 / (sum of train miles and employee hours)
- Employee casualty rate: number of fatalities and non fatal conditions per 200,000 hours
- Train accident rate: number of accidents per million train miles
- Yard accident rate: number of yard accidents per million yard switching miles
- Highway Rail incident rate: number of accidents per million train miles
- Trespasser casualty rate: total fatalities and injuries per million train miles

RESULTS FOR AMTRAK AND MAJOR FREIGHT RAILROADS ARE AVAILABLE TO THE PUBLIC THROUGH THE FRA OFFICE OF SAFETY ANALYSIS WEBSITE

IV. CONCLUSIONS

THE DISCUSSION FRAMEWORK AND DATA COLLECTION EFFORTS YIELD SOME IMPORTANT LESSONS

- The quality of the data is generally best for heavy rail systems, reasonably good for light rail systems and worst for bus. Automatic vehicle locator technology (AVL), however, will dramatically improve bus data in a few years

- Travel time and delay can be derived for most transit properties based on the schedule. Where the schedule is not available, it may be possible to estimate travel time and delays based on published headway (e.g., buses every 20 minutes) and other information

- Reliability indicators can only be developed for systems that maintain detailed travel time data

- Transit agencies and metropolitan planning organizations have developed some useful approaches to study accessibility. Applying the accessibility indicator to the transportation system can be done immediately

- Safety measures can be incorporated as a state-wide multimodal indicator. In addition, security measures can be reported even though there is no equivalent in other modes

AS ANTICIPATED, THE MAIN CHALLENGES RELATED TO APPLYING THE INDICATORS RELATE TO THE NUMBER OF SOURCES, DATA AVAILABILITY AND DIFFERENCES IN REPORTING

- Data collection can be resource intensive – For a large urban area (e.g., Los Angeles basin, San Francisco-Oakland-San Jose), collecting transit system performance measurement data encompasses multiple systems. Additionally, some transit agencies (e.g., bus operators) do not yet maintain all mobility data in electronic form; this would need to be entered in manually. However, a consistent handling of transportation outputs by line will help analyze and calculate the performance indicators

- In some cases, data is unavailable – Bus companies sometimes don't publish schedules, advertizing headways to their customers instead. For others, detailed origin to destination travel time data is not available. In these situations, the recommended approach is to rely upon statistical "sampling" data instead for the calculation of the indicators

- These data collection-related challenges can be mitigated and addressed if approached rationally. In efforts to calculate performance indicators, the "setting up" stage for the first year would not have to be repeated for subsequent years

GENERALLY, AGENCIES SEEM OPEN TO PROVIDING THIS DATA TO CALTRANS FOR ANALYSIS

IT IS FEASIBLE TO APPLY SYSTEM PERFORMANCE INDICATORS TO TRANSIT FOR MOBILITY, RELIABILITY AND SAFETY OUTCOMES AS ILLUSTRATED BY THE RECOMMENDATIONS BELOW

OUTCOME	INDICATOR	APPROACH
Mobility	Travel time	Obtained from schedule or trip tables
Mobility	Lost time (delay)	Calculation based difference between actual and optimal
Accessibility	Demographic data within radius of rail station/bus stop (e.g., 0.25 mile)	Combined use of GIS and up to date census data
Reliability	Standard deviation of travel time variability	Calculation of standard deviation of travel time events in excess of average
Safety	Safety rates: - fatality rates per vehicle mile - injury rates per vehicle mile	In-station or right-of-way events can be wrapped into safety rates to account for the total safety indicator for that mode
Security	Crime events: - Part 1 crime offenses - Part 2 crime offenses	Crime events can be collected and aggregated by region but they have no corresponding highway measure

APPENDIX – INTERVIEW RESULTS

ROUTE AND OPERATIONS FINDINGS FOR BUS AND LIGHT RAIL…

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Route	Over 100 routes within seven subsectors	29 routes	2 routes, Blue and Orange lines
Route Length	630 miles	635 miles	40 miles
Service Frequency	7.5-30 min. (week days) 20-60 min. (week-ends)	6-30 minutes (week days) 12-60 minutes (week-ends)	8 trains per hour during peak 4 trains for Orange line
Service Provision	6,200 trips/day 200,000 boardings/day	Approx. 2,200 bus trips per day	103 trains per day (Blue) 72 trains per day (Orange)

SCHEDULE FINDINGS FOR BUS AND LIGHT RAIL…

Operator	AC Transit	San Diego Transit	San Diego Trolley
Schedule			
Scheduled Travel Time	30 to 120 minutes	36 to 120 minutes	61 minutes (Orange Line) 69 minutes (Blue Line)
Dwells	No minimum dwell times; drivers stop only when passengers	No minimum dwell times; drivers stop only when passengers	25 seconds
Speeds	Street posted speeds. The Transbay network to San Francisco is designed for speed	Variable; limited by surface street posted speeds	Trains are *required* to operate a maximum authorized speed (55 mph on open terrain, 25 mph in CBD)
Accel./ Deceleration	N/A	N/A	N/A
Padding	10 percent slack is built into the schedule to account for wheelchair lifts, safety stops. Five extra minutes layover are scheduled at the end of line	None; schedule is constructed empirically by averaging actual run times	2 minute "fudge factor" applied due to mixed traffic conditions in CBD for both lines
Operations remarks	Rail safety stops are required throughout region		Mixed ROW for both Blue and Orange lines in CBD
Average speed	12.5 mph (includes stops) 7 mph in Oakland CBD	14.3 mph (includes stops) No distinction for CBD	23 mph in the open, 18 in CBD

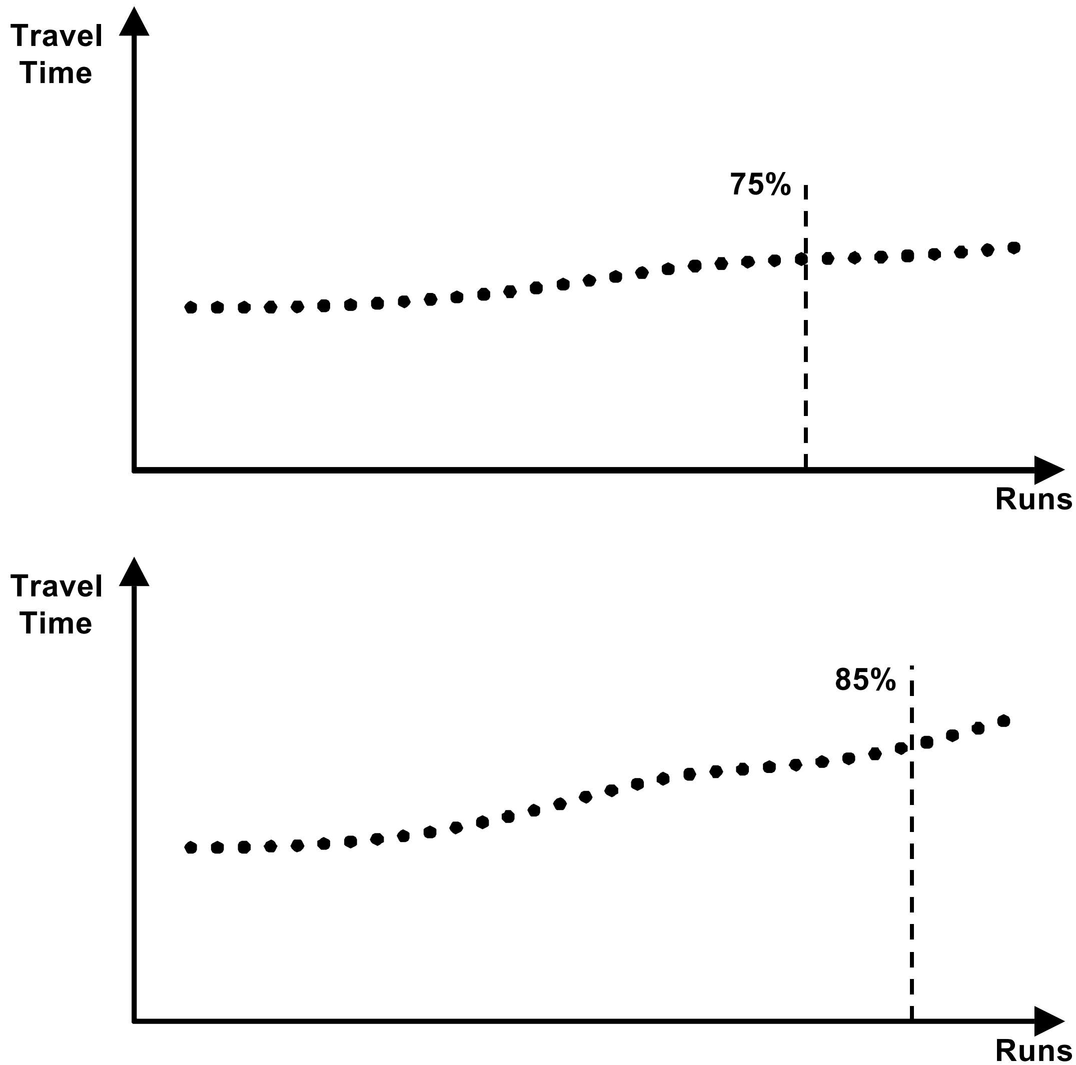
ROUTE AND OPERATIONS FINDINGS FOR HEAVY AND COMMUTER RAIL…

Operator	BART - Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
Route	5 routes	6 routes
Route Length	93 miles	416 route miles
Service Frequency	Every 5 to 20 minutes	For most lines, 30 minutes during peak, 60 minutes during off peak
Service Provision	Approximately 650 train dispatches per day, 487 cars used in peak (PM rush)	126 trains per day, primarily peak direction service

SCHEDULE FINDINGS FOR HEAVY AND COMMUTER RAIL…

Operator	BART - Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
Scheduled Travel Time	51 to 73 minutes Most lines approximately 1 hour	40 to 105 minutes
Dwells	35-40 seconds in downtown SF; 10-15 seconds in outlying areas	40 seconds
Speeds	Most trains run at Performance Level 2, which is one notch below maximum authorized speed (PL 1 is 80 mph in Transbay Tube)	FRA requires trains to operate at maximum authorized speed. Top speed is 90 mph in Automatic Track Signal section; 79 mph elsewhere
Accel./ Deceleration	Trains operate at half or full acceleration (3.2 mph/sec)	N/A
Padding	Schedule developed empirically by using percentile of average runs and average dwells, results in approximately 2 to 3 minutes of padding	Recovery time is added to schedule just before last station (5-15% of end-to-end travel time, depending on other traffic on line)
Operations remarks	Computer controls performance characteristics (maximum speed, acceleration, etc.)	Own one right-of-way, have trackage rights on others. Share all tracks with Amtrak and/or freight trains
Average speed	45 mph in outlying areas, 36 mph in CBDs	45 mph (systemwide, including stops)

BART'S Run Profile Based Approach



Note: BART analyzes the profile of run times, and sets a schedule run time that encompasses the majority of cases. The scheduled run time corresponds to a given percentile of runs (e.g., 75%, 85%) chosen depending on the spread of the distribution.

ROUTE, OPERATIONS FINDINGS FOR INTER-CITY RAIL…

Operator	BART - Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
Route	Capital Corridor	San Joaquin
Route Length	89 miles – Oakland to Sacramento	315 miles
Service Frequency	Departures every two hours approximately	Departures every three to four hours
Service Provision	6 trips per day per direction	4 trips per day per direction

SCHEDULE FINDINGS FOR INTER-CITY RAIL…

Operator	BART - Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
Schedule		
Scheduled Travel Time	130 minutes	6 hours, 5 minutes
Dwells	1 to 3 minutes at each station, even less at detraining (no pick-up, only drop-off) stations	2 minutes at most stations; 4 minutes at several hubs
Speeds	Trains are *required* to operate at maximum authorized speed. Different speed orders for specific sections of track (tops speed is 79 mph)	Trains are *required* to operate a maximum authorized speed. Different speed orders for specific sections of track (top speed is 79 mph)
Accel./ Deceleration	Approximately 3 minutes to decelerate to full stop	Approximately 3 minutes
Padding	Schedule developed using normal run time and station dwells plus 8% padding at end of schedule (8% more time than run time)	6 to 8% of total travel time
Operations remarks	Union Pacific controls dispatching and Amtrak operates service	Priority depends; Amtrak share ROW with freight trains
Average speed	50 mph on entire length	50 mph on entire length

FINDINGS RELATED TO DELAY FOR BUS AND LIGHT RAIL TRANSIT…

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Definition of Delay	Over 5 minutes late from schedule	Over 5 minutes late from schedule (goals are set yearly)	Over 5 minutes late from schedule
Delay Threshold as a Percent of One-Way Schedule	4.2% - 16.7%	4.2% - 13.8%	7.2% - 8.2%
Remarks on Delay	If running late, the drivers will call in to central dispatch to ask for guidance	Drivers must call in if they are running more than 10 minutes late	SDTI places more emphasis on the delay causing events than on the total number of minutes late. Both are captured in the "Record of Train Movement Report" (RTM)
Ability to Make Up Time	The drivers use 4-5 techniques to catch up delays, primarily skipping stops. One of the main limitations faced by AC transit is lack of spares to make up time (the only route they have ready buses is for the transbay service)	It is very difficult to make up time; drivers stop when requested and cannot exceed the posted speed	Dwells are already very short (25 secs) and trains are required to operate at maximum authorized speed. The only way is to skip stops (which is done occasionally) but little time is gained

FINDINGS RELATED TO DELAY FOR HEAVY AND COMMUTER RAIL…

Operator	BART - Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
Definition of Delay	Over 5 minutes late from schedule at end of run	6 or more minutes late at final destination (including scheduled recovery)
Delay Threshold as a Percent of Schedule	6.8% - 9.8%	5.7% - 15%
Remarks on Delay	Passengers on-time considered more important than trains on-time	Conductors maintain delay sheets (showing minutes of delay and events causing delay) for entire trip, even if train is not late at final destination
Ability to Make Up Time	Computers automatically adjust dwells when train is delayed. Train control center can (but not often) adopt higher performance levels, which effect speed and acceleration	Limited to recovery time before final destination. Dwells and speeds are fixed, so there is little flexibility to make up time.

FINDINGS RELATED TO DELAY FOR INTER-CITY RAIL…

Operator	BART – Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
Definition of Delay	Arriving at end station more than 10 minutes past scheduled time	Delayed trains are trains 15 minutes late based on the schedule
Delay Threshold as a Percent of One-Way Schedule	8% - 8.3%	4.1%
Remarks on Delay	Service is in transition	Being on schedule is the top priority. Anything that interferes is considered a delay. Being on time, especially at the end of line is critical because of the bus connections
Ability to Make Up Time	Trains can make-up time only be shortening dwells, but trains cannot leave station early.	Operators do not have much latitude in making up time - speeds are already the maximum authorized and minimum dwells are fixed

DELAY MEASUREMENT FINDINGS (BUS AND LIGHT RAIL TRANSIT)…

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
On-Time and Delay Measurement	13 samples are taken every quarter at major bus centers. This accounts for about 10% of all trips (e.g., 460 samples from 6,200 trips)	There is no bus-by-bus capture of travel time by operators. Inspectors must be sent into the field and time buses at randomly selected stops. Automatic Vehicle Locator (AVL) systems will start being installed next year (5 year program)	The RTM reports all actual travel time runs for the trolleys.
Database Details	Central Dispatch Database	No database	RTM Record Database

STATISTICAL REPORTS (BUS AND LIGHT RAIL TRANSIT)…

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Statistical Reports	**On-Time Performance Report** (monthly, system-wide and route-by-route; sharps, lates, trips on-time, percent on-time. **Incident Report** (detailed & summary, by incid. type) **Delays in Service Report** (shows run number, coach number, reason and delay) **Out Lates Report** (shows run number, coach number, reason and delay)	**On-Time Performance Report** (monthly, shows delay events greater than 5 minutes based on inspection)	**Record of Train Movement Report** (RTM - shows trip time to the minute for each train movement) **Route Summary Report** (daily - shows trains and % trains 20+, 10-19, 6-9, 4-5, 0-3, -1, -2 to -3, -4+ minutes late (early)) **Incident Summary** (shows delay events for Transportation, Wayside, LRV)
Percent of Total Runs Captured in Statistics	10% for On-Time Performance Report, 100% for other reports	4.5%	100%

DELAY MEASUREMENT AND STATISTICAL REPORTS (HEAVY AND COMMUTER RAIL)…

Operator	BART - Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
On-Time and Delay Measurement	Train control computer compiles electronic database of train movements. Fare gates record passenger entry and exit. Control center compiles delay cause	Conductors maintain delay sheet for each trip, showing causes and minutes of delay. Data are coded to TRMS (Train Record Management System) database
Database Details	Central computer records: times trains enter blocks, doors open and close, and trains released from station. Fare gates record station entries and exits	TRMS data base used to report on-time performance, frequency and causes of train delays (can be made available to Caltrans)
Statistical Reports	**System Performance Summary** (weekly, shows ridership, car hours, cars causing repeat delay) **Service Performance**	**Metrolink Performance Summaries** (monthly Board report) **Ad-hoc On-Time Performance** (measures passengers on time) **Morning Report** (daily summary of prior day's operating data, including train-by-train detail) **On-Time Performance Analysis** (daily data, by train) also **Train History Report**
Percent of Total Runs Captured in Statistics	100%	100%

DELAY MEASUREMENT AND STATISTICAL REPORTS (INTER-CITY RAIL)…

Operator	BART – Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
On-Time and Delay Measurement	Delay statistics compiled manually	The Engineer and Conductor on board manually compile the delay cause and duration as they occur, then the final arrival times. The Operations Control Center daily inputs the data in a central database
Database Details	Delay statistics kept by Amtrak. Capitol Corridor receives daily hard copy output from Arrow database.	7-day storage database (Arrow), long term storage in Los Angeles
Statistical Reports	**On-Time Performance** (monthly, shows percent of trains on-time, reviewed monthly by Capital Corridor Joint Powers Board)	**On-Time Performance** (monthly - shows trains operated, trains on time, and percent on time as well as the goal for each route) **Delay Summary** (monthly - shows for each line the delay type and total minutes of delay associated with each)
Percent of Total Runs Captured in Statistics	100%	100%

AMONG THE AGENCIES INTERVIEWED SANDAG AND BART HAVE DRIVEN THE FURTHEST IN TERMS OF THE ACCESSIBILITY INDICATORS ENVISIONED IN THE STUDY – ACCESSIBILITY TO TRANSPORTATION NETWORK AND TO DESIRED LOCATIONS

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- AC Transit:
  - believe the network provides 90 percent of patrons a bus stop within 0.25 mile walk
  - is using plotting maps provided by MTC
  - currently migrating from MapInfo to ArcView
  - SatCom 2000 project will include 100 percent AVL on buses by 2002-2003. The project aims to provide a real time ability to communicate with passengers at key stops. SatCom will be fully linked to Trapeze, the scheduling system

TRAVEL TIME RELIABILITY DATA IS NOT ROUTINELY COLLECTED FOR BUS AND LIGHT RAIL

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Travel Time Reliability	Daily ridership varies by 10-15% for many reasons. There is no ability to "thin out" service on light days and augment svc on heavy days. There are over 100 wheelchair boardings per day	Not currently calculated	Reliability is not studied in terms of deviation from travel time. On-time arrival is more important to passengers than total travel time
Suggested Approach	Statistically analyzing the Central Dispatch Database for travel time reliability has not been done and would be useful	Wait until AVL is installed for the fleet for comprehensive, error free reliability calculation In the meantime, would have to rely on 4.5% sample	Would have to use RTM form, but it is manual and not electronic yet

BART IS THE ONLY AGENCY INTERVIEWED TO SYSTEMATICALLY ANALYZE RELIABILITY – THROUGH HISTOGRAMS

Operator	BART - Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
Travel Time Reliability	Do not consider travel time reliability to be important because of exclusive right-of-way. Focus on on-time arrivals	Defined in terms of passenger on-time performance (i.e., relates passengers on-board to on-time performance at final station; doesn't capture delay at intermediate stations)
Suggested Approach	Recommend using frequencies or histograms. Reliability is not likely to be normally distributed for BART	In the process of evaluating standard deviation of travel time. This is an ongoing effort by the Operations Department; there are no results yet

TRAVEL TIME RELIABILITY DATA IS NOT ROUTINELY COLLECTED FOR INTER-CITY RAIL

Operator	BART – Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
Travel Time Reliability	Focus on on-time arrivals. Examine distribution plot of delay (arrival 10 minutes past scheduled time)	Not currently calculated
Suggested Approach	Hard to measure statistically, since only 6 trains are run daily	Suggest calculating variability in travel time from schedule

SAFETY DATA ARE ROUTINELY COLLECTED BY THE PEER AGENCIES

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Safety Reporting Requirements	Report to FTA through National Transit Database	San Diego Trolley is responsible for safety reporting	Most complete reporting requirements are to the Public Utilities Commission (PUC) FTA requirements Internal requirements for Board
Safety Reports	NTD (Section 15) Monthly Accident Summary (internal document): Collisions description, accidents per 100,000 bus miles	**Risk Activity Report** (monthly) - includes: Accidents (collision, non-collision, total, injury/damage) Breaks out preventable versus non-preventable accidents and presents ratios (e.g., per 100k miles)	**Risk Activity Report** (monthly) - includes: Accidents (collision, non-collision, total, injury/damage) Breaks out preventable versus non-preventable accidents and presents ratios (e.g., per 100k miles) **Safety Accident Report** (annual summary)
Safety Indicators	- Accidents per 100,000 buses miles (69 different accident categories)	Presented to Board: Accidents per 100,000 bus miles (aggregate, difference with previous month and % variance)	- LRV/auto accidents by line - LRV/pedestrian accidents by line - total accidents - personal injuries by type - medical emergencies - employee emergencies

SECURITY DATA ARE ROUTINELY COLLECTED BY THE PEER AGENCIES - FREQUENTLY BY A SECURITY OR POLICE DEPARTMENT

Operator	AC Transit	San Diego Transit	San Diego Trolley
Mode	Bus	Bus	Light Rail
Security Reporting Requirements	The only requirement is for the FTA, the National Transit Database (Transit and	San Diego Trolley is responsible for security reporting	Database for crime rates is based on FTA Sec. 405 and includes 18 categories Reported to Board quarterly
Security Reports	NTD Report, Transit Safety and Security Form (405)	See SD Trolley	**Crime Statistics Report** (quarterly, yearly summary)
Security Indicators	Part I, report eight offenses Part II, arrests	See SD Trolley	**Part I Offenses (events)** for Violent Crime (homicide, rape, robbery, aggravated assault) and Property Crime (burglary, larceny/ theft, motor vehicle theft, arson) **Part 2 Offenses** (events) includes categories for vandalism, sex offenses, drug abuse violations, driving under the influence, drunkenness, disorderly conduct, trespassing, fare evasion, curfew and loitering laws, and other

SAFETY FINDINGS FOR HEAVY AND COMMUTER RAIL…

Operator	**BART – Heavy Rail**	**Metrolink**
Mode	Heavy Rail	Commuter Rail
Safety Reporting Requirements	Safety statistics reported to PUC.	Accident reporting is mandated by the Federal Railroad Administration
Safety Reports	**Monthly Accident and Unacceptable Hazardous Condition Summary Report**: derailment, collision, fire incidents, other accidents. Reports also submitted by major incident to PUC.	Railroad Injury and Illness Summary Rail Equipment Accident/Incident Report Highway-Rail Grade Crossing Accident/Incident Report
Safety Indicators	Station incidents per million patrons Vehicle incidents per million patrons Lost time injuries/illnesses per million hours OSHA recoverable injuries per million hours Unscheduled door openings per million car miles Rule violations summary by million car miles	- fatalities per 100,000 train miles - fatalities per 100 million unlinked trips - injuries (all types) - incidents (gate running, trespasser, vandalism)

SECURITY FINDINGS FOR HEAVY AND COMMUTER RAIL…

Operator	BART – Heavy Rail	Metrolink
Mode	Heavy Rail	Commuter Rail
Security Reporting Requirements	Federal government requires Uniform Crime Report (UCR) to be submitted to state monthly	Crimes are reported quarterly for all lines
Security Reports	**Quarterly Operations Report** includes quality of life violations, auto theft, burglary. **BART Police Department Monthly Statistical Report**- broken down by type of incident. **Daily operations report** includes number of police incidents. BART police arrest database	Quarterly report includes: - Part 1 crimes (events for incidents, adults arrested and juveniles arrested) – criminal homicide, rape, robbery, aggravated assault, burglary, larceny theft, grand theft auto, arson - Part 2 crimes – forgery, fraud, sex offenses, vandalism, 12 others -
Security Indicators	All indicators are "events" Part 1 crime Crimes against persons - trains - parking lots - stations Auto theft Auto burglary	- Part 1 crimes by category - Part 2 crimes by category

SAFETY FINDINGS FOR INTER-CITY RAIL…

Operator	BART – Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
Safety Reporting Requirements	Federal Railroad Administration requires carrier to report accident data for damage over a threshold, fatalities, and certain injuries.	Accident reporting is mandated by the Federal Railroad Administration for both passengers and employees[1]
Safety Reports	Only collect major event information. Operator handles safety and accident reporting.	**Customer and Employee and Trespassers Injury Statistics** Includes: Class A, B (employee reportable) Class C (customers on train) Class D (off train injuries) Class E (injuries and fatalities)
Safety Indicators	See FRA safety indicators	See FRA safety indicators

1 *The FRA, Office of Safety Analysis, maintains a website with rail accident/indicent information including accident/incident details, graphs & charts. One has the ability to query accident data as well as access accident summaries bycause, by type, by State and by major Class 1 carriers.*

SEPARATELY FROM AMTRAK, THE FEDERAL RAILROAD ADMINISTRATION, OFFICE OF SAFETY ANALYSIS, ROUTINELY TRACKS SIX SAFETY INDICATORS

- Total accident/incident rate: reported events x 1,000,000 / (sum of train miles and employee hours)
- Employee casualty rate: number of fatalities and non fatal conditions per 200,000 hours
- Train accident rate: number of accidents per million train miles
- Yard accident rate: number of yard accidents per million yard switching miles
- Highway Rail incident rate: number of accidents per million train miles
- Trespasser casualty rate: total fatalities and injuries per million train miles

RESULTS FOR AMTRAK AND MAJOR FREIGHT RAILROADS ARE AVAILABLE TO THE PUBLIC THROUGH THE FRA OFFICE OF SAFETY ANALYSIS WEBSITE

SAFETY AND SECURITY DATA ARE ROUTINELY COLLECTED BY THE PEER AGENCIES - FREQUENTLY BY A SECURITY OR POLICE DEPARTMENT

Operator	BART – Capitol	Amtrak – San Joaquin
Mode	Inter-City Rail	Inter-City Rail
Security Reporting Requirements	None	Administered by Amtrak police department and local police
Security Reports	Very little data available. Parking lots are owned by cities or Union Pacific	Only available through Amtrak Philadelphia office
Security Indicators	None	Only available through Amtrak Philadelphia office

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures Applicability of Indicators to Goods Movement

Technical Memorandum

Booz·Allen & Hamilton Inc.
June 30, 1999

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EXECUTIVE SUMMARY

This document represents the technical memorandum for the freight research task in the Performance Measurement initiative currently led by the California Department of Transportation (Caltrans). The task addresses research performed by Booz·Allen & Hamilton regarding the applicability of performance indicators to the goods movement market.

- The main finding is that it is feasible for the State and regional partners to apply performance measures in a manner that encompasses freight
- The most applicable outcomes are: safety / security; reliability; mobility / accessibility; equity; economic well-being; and environmental quality
- Indicators identified for the highway and transit modes, in some cases with minor modifications, can address truck and freight rail activity. For some indicators, data limitations will not allow a comprehensive analysis of the freight markets separately (e.g., delay for rural areas)
- Some of the indicators can be used only for monitoring, some only for forecasting, and some for both.

The following table summarizes findings, conclusions and recommendations for each outcome area.

SUMMARY FINDINGS

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	IMPLEMENTATION RECOMMENDATIONS
Safety / Security	Safety Rates	• Safety rates are mandated and reported by freight rail carriers • Safety rates for trucks are collected by the California Highway Patrol	Use safety rates as indicator for the safety and security outcome	• Use consistent units for safety rates • Develop baseline safety rates for regions / State to monitor and report safety for improvements
Reliability	Standard Deviation of Travel Time	• Reliability of travel time can be calculated for non-recurrent delay for both truck and rail • Reliability for trucks will be the same as the reliability for the highway mode[1]	Use the standard deviation of travel time variability in excess of the mean (auto and truck) as indicator for reliability	• Develop baseline reliability for regions / State to monitor and report reliability for improvements

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1 *Applicability of Indicators to Highways, Booz Allen & Hamilton, June 1999*

SUMMARY FINDINGS, CONTINUED

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	IMPLEMENTATION RECOMMENDATIONS
Mobility / Accessibility	Travel Time	• Travel time can be derived from highway inductive loops and freight railroad data	Use travel time as the first indicator for freight mobility	• Use loop data as basis for determining travel time (auto / truck) • Use freight railroad data as basis for determining travel time for rail • Develop a baseline travel time for regions / State to monitor, forecast and report travel time for improvements
	Delay (Lost Time)	• Delay (lost time or recurrent delay) can be calculated based on the difference between actual and optimal travel times • Optimal travel times are based on posted speeds (i.e., uncongested speeds) for both truck and rail	Use delay as the second indicator for freight mobility	• Define delay as the difference between actual and optimal travel time calculations to determine delay for truck and rail • Develop a baseline delay for regions / State to monitor, forecast and report delay for improvements
	Accessibility to Intermodal Facilities	• Access to intermodal facilities is limited due to parking restrictions and hours of operation	Use accessibility to intermodal facilities as indicator for freight accessibility	• Refine facilities to include in accessibility (e.g., ports) • Work with regions and facilities to develop consistent GIS interface to map accessibility • Develop baseline accessibility for regions / State to monitor, forecast and report accessibility for improvements

SUMMARY FINDINGS, CONTINUED

OUTCOME	INDICATOR	FINDINGS	CONCLUSIONS	IMPLEMENTATION RECOMMENDATIONS
Equity	Regional Share of Mobility Benefits	• The urban / rural split of projects dedicated to goods movement is an equity concern • Breakdown of urban / rural cost components for projects can be achieved • Equity concerns between modes is a giant issue: an investment of public dollars in one mode will put the other modes at competitive disadvantage • Another large equity issue is the investment of public dollars for goods movement project versus person movement improvement projects	Costs do not equate to benefits. A better way of determining benefits needs to be researched. In addition, more research and consensus building needs to be undertaken to define how equity will be measured	• Track project costs for freight improvement projects • Develop a consistent definition of urban and rural areas • Research better ways of measuring mobility benefits and how equity should be measured • Test the equity indicator as the income group share of mobility benefits, defined as benefits in time saved from transportation improvement
Economic Well-Being	Final Demand	• There are three primary ways to define and apply the final demand indicator • The indicator is best used for forecasting	Use final demand for freight industry services as the indicator for goods movement economic well-being	• Apply the indicator to goods movement by measuring final demand in freight-related transportation industries • Continue to examine the applicability of the REMI regional economic model as analysis tool • Develop baseline economic well-being for regions / State to forecast and report on indicator
Environ-mental Quality	Environmental Indicators	• Both the State through the Air Resources Board and the Federal Government (through the Environmental Protection Agency) require project reporting	Use the environmental indicators already mandated for State and federal regulations	• Use mandated environmental indicators • Develop baseline environmental quality for regions / State to monitor, forecast and report for improvements

This document represents the technical memorandum for Task 3 in the Performance Measurement initiative currently led by the California Department of Transportation (Caltrans). The task addresses research performed by Booz·Allen & Hamilton regarding the applicability of performance indicators to the goods movement market.

1. APPROACH

The team's approach was driven by the following elements:

- The evaluation was to focus on the most relevant outcomes in the performance measurement framework

- The evaluation needed to address how the State and regions can apply performance measures in a manner that encompasses freight, both from a monitoring and forecasting point of view

- The goods movement markets considered in the analysis include the highway (i.e., truck trailer and less-than-truckload traffic) and railroads (i.e., short-line and Class I railroads) in California

- Discussions included input from the team which developed the freight module of the California Transportation Plan (CTP), from the System Measures Working Group (SMWG), and from Booz·Allen freight professionals.

Preliminary results from the interviews and research were presented on May 17, 1999 to the SMWG, which provided feedback. Input from that meeting and additional feedback from the SMWG has been incorporated into this technical memorandum.

2. RESULTS

In the initial discussions with Caltrans staff, four outcomes were selected as being the most applicable to the goods movement market: reliability, mobility and accessibility, safety, and equity. Subsequent interviewees confirmed the adequacy of this selection, and brought up potential benefits in tracking other outcomes, such as economic well-being and environmental quality. Other individuals expressed the opinion that all outcomes listed in the performance measure framework can be tied to goods movement at some level. For example, customer satisfaction can be interpreted as shipper satisfaction, and sustainability can be interpreted as the sustainability of shipper’s costs. However, the SMWG agreed that the proper way to proceed with regards to goods movement is to select a subset of the most appropriate outcomes, develop corresponding measures, and then implement for monitoring and forecasting, as appropriate.

The exhibit below shows the six areas of outcomes that are most applicable to goods movement. The nine base system outcomes listed are fully described in the Transportation System Performance Measures, Final Report.

System Performance Outcomes		Goods Movement Outcomes
• Mobility / Accessibility		• Mobility / Accessibility
• Reliability		• Reliability
• Cost effectiveness		
• Economic well-being	→	• Economic well-being
• Sustainability		
• Environmental quality		• Environmental quality
• Safety and security		• Safety and security
• Equity		• Equity
• Customer satisfaction		

In the remainder of this document, each of these areas is discussed in the order of importance attributed by the individuals interviewed. How to implement candidate indicators is also discussed for each outcome.

2.1 Safety

Safety was identified as a critical outcome for applicability to goods movement by all interviewed. The sentiment was echoed during the SMWG discussions.

2.1.1 Industry Perspective

Safety is critical to the trucking industry for many reasons: liability, industry reputation, potential revenue loss and productivity. The industry pays close attention to trends involving accidents, fatalities, property damage and other safety-related factors.

Safety also has enormous consequences for freight railroads due to liability implications, as well as operational disruptions given the lack of alternate routes. Grade crossing and grade separation situations generate unique safety risks which are actively monitored by the railroads and the Public Utilities Commission (PUC). Please refer to the description on the following page for more details on the PUC.

CALIFORNIA PUBLIC UTILITIES COMMISSION – AT A GLANCE

Rail Safety and Carriers Division:
The Rail Safety & Carriers Division licenses motor carriers of passengers and freight, promoting safe highway operation and assuring carriers maintain adequate insurance coverage. It regulates movers to assure consumers are adequately protected and also oversees railroad, light rail transit and stationary utility safety.

Goals and Objectives:
To make certain railroad-highway grade crossings are designed, constructed, and properly maintained to ensure the public safety.

Functions:
Rail Crossings Engineering Section seeks to improve the safety of public railroad-highway crossings in California by performing the following functions:

1. Review formal Applications for new crossings and grade separations or alterations to existing crossings. Recommend Commission approval or denial.
2. Conduct diagnostic meetings and inspections at railroad and rail transit crossings as needed.
3. Enforce Public Utilities Code and General Orders relating to railroad crossings, particularly PUC Code Sections 1201-1205 and General Orders No. 75-C.
4. Section 130 Federal Funding- Annual list of at-grade crossings recommended for improvements.
5. Maintain the Railroad-Highway Crossing Database.

Reporting:
No safety data is currently posted on the Web. The PUC publishes the Annual Report of Railroad Accidents Occurring in California, through which safety data is reported for all light rail and freight railroad systems in the State.

The following excerpts are from the 1997 report: "… Part I identifies all reported accidents and injuries on railroad property, and any accident or incident connected with a railroad operation. In 1997, California freight railroads operated 25.63 million train miles, an increase of 18% over 1996, while the number of accidents (123) decreased by 11%. One train employee was killed on the job in 1997, and 200 were injured. The train accidents for 1997 resulted in a loss of 12.6 million dollars, an increase of about 10% from 1996.

Part II covers accidents at railroad grade crossings, and accidents involving trespassers. In 1997, there were 159 accidents at railroad crossings, resulting in 22 deaths and 43 injuries. The number of railroad grade crossing accidents decreased 20.9% from 1996 and casualties declined by 16.7%."

2.1.2 Data Availability

2.1.2.1 Truck Safety - Truck safety data are fairly difficult to access. To our knowledge there are no annual publications that specifically break down safety trends for the trucking industry in California. At the moment the sequence of reporting events is as follows:

- The California Highway Patrol (CHP) completes an accident report for each accident reported to law enforcement
- The reports are compiled in the CHP-maintained Statewide Integrated Traffic Record System (SWITRS)
- Caltrans also receives copies of the accident reports, which are coded a second time into the Traffic Accident Surveillance Analysis System (TASAS)
- The U.S. Department of Transportation aggregates these safety data at the national level (e.g., National Highway Traffic Safety Administration, National Center for Statistics and Analysis, Traffic Safety Facts 1997). However, the annual report does not break down the data by state.

The Caltrans equivalent to the U.S. DOT *Traffic Safety Facts* is the Caltrans *Accident Data on California State Highways*, which is published annually. However, the safety data are not broken down by mode in this publication.

Caltrans estimates that the TASAS database reaches 100 percent of fatality accidents and about 80 percent of injury accidents. All accidents involving property damage in excess of $500 are supposed to be reported. However, Caltrans estimates that only 40 percent of those are reported in TASAS. Finally, note that neither the California Highway Patrol nor Caltrans currently collect the property damage estimate for each accident.

The truck safety data from TASAS and SWITRS are available to external agencies in response to written requests, and are analyzed by Caltrans periodically (e.g., for TCR development).

2.1.2.2 Railroad Safety - Rail safety data in California are tracked by the PUC and the Federal Railroad Administration (FRA). Railroad and light rail accidents and casualty data must be reported to these two agencies by law. Data required for performance measure calculations are published annually by the PUC in its Annual Report of Railroad Accidents Occurring in California. The data are available to significant levels of detail as illustrated in the example for rail crossing statistics below.

ILLUSTRATIVE

RAILROAD	COUNTY	CITY	HIGHWAY	DATE	TIME	VEHICLE SPEED	VEHICLE DAMAGE	TOTAL KILLED	TOTAL INJURED
ATK	ALAMEDA	HAYWARD	CLAWITER RD	10-Nov	955AM	1	$7,000	0	1
UP	ALAMEDA	KOHLER	MARINA	7-Jan	620PM	0	$4,000	0	4
BNSF	FRESNO	FRESNO	NORT AVE	1-Dec	345PM	0	$5,000	0	0
SJVR	KERN	BAKERSFIELD	MONTICELLO ST	12-Jan	715PM	1	$0	0	0
UP	KERN	MOJAVE	SOPP RD	23-Dec	815PM	3	$1,000	0	1
SCAX	LOS ANGELES	COVINA	GRAND AVE	25-Jun	820AM	0	$8,000	1	0

2.1.3 Safety Indicators

Safety indicators for goods movement should be developed based on the base data available (e.g., number of accidents, victims, vehicle miles traveled)

2.1.3.1 Truck Indicators - For truck movements, two candidate indicators are currently used in the Caltrans *Accident Data on California State Highways:*

- Accident Rate = (number of accidents) x 1,000,000 / Vehicle Miles Traveled[2]
- Fatality Rate = (number of fatalities) x 100,000,000 / Vehicle Miles Traveled[3]

This list can be expanded to include total accidents, total fatalities, and injury rates depending on the base data available. Calculation of indicators will be made easier given that TASAS is an in-house database.

2.1.3.2 Railroad Indicators - For rail movements, two indicators published by the PUC and FRA merit consideration for Caltrans:

- Accident Rate = (number of train accidents) / million train miles
- Casualty Rate = (number of victims) / million train miles

Train accidents are defined as accidents meeting the threshold reporting requirement of FRA Form 54 which are: collisions (excluding most grade crossing accidents), derailments, fires, explosions, natural disasters, and other events involving the operation of on-track equipment (standing or moving) and causing more than $6,300 of reportable damage.[4]

Casualties are defined as any event connected with a railroad operation resulting in one or more of the following consequences that must be reported on Form FRA F 6180.55a:

2 *Truck miles*

3 *Truck miles*

4 *Source: Annual Report of Railroad Accidents Occurring in California, California Public Utilities Commission, 1997.*

- Death of a person within 365 days of the accident/incident
- Injury to a person, other than a railroad employee, that requires medical treatment
- Injury to a railroad employee that requires medical treatment or results in restriction of work for one or more work days, the loss of one or more work days, termination of employment (as interpreted by FRA), transfer to another job, or loss of consciousness
- Any occupational illness of a railroad employee.[5]

Therefore, safety indicators at grade crossings are not developed separately at the PUC. Individual occurrences are tracked, but overall grade crossing safety is subsumed in the overall rail safety indicator.

2.1.4 Application of Indicators

Caltrans and other regional transportation agencies should adopt accident rates as defined by Caltrans and the PUC for truck and rail safety, respectively. To the extent possible, the units defined by this performance measure must be consistent between each other and with units tracked for transit (bus, light rail, commuter rail) and the highway mode (auto). The analysis can be shown by mode, as well as by region[6]. Grade crossing accidents, which are point events, should be reported separately.

Currently, the thresholds for accident reporting are slightly different for truck and rail. Truck's threshold is $500 while rail's is $6,300. Given that no data sources currently exist for mitigating this difference, proper documentation is recommended to clarify what is being reported.

Unless one relies on trend analyses for forecasting safety rates, safety indicators will primarily be a monitoring tool for the State and regions.

2.2 Reliability

2.2.1 Industry Perspective

Reliability is one of the most important outcomes for California shippers. Given the limited customer hours of operation and "Just In Time" (JIT) practices now common in the industry, reliability is one of the most critical pieces of information not currently available to shippers.

In metropolitan areas, truckers are often held up in traffic congestion. Customers are open for business for a limited number of hours (e.g., 8 a.m. to 5 p.m.). Express

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5 *Source: FRA Guide for Preparing Accident/Incident Reports, U.S. Department of Transportation, 1997.*

6 *State of the System Report Design, Booz Allen & Hamilton, June 1999*

shipping and express mail follow even narrower delivery hours (e.g., 7 a.m. to 10 a.m. for early morning delivery, 11 a.m. to 2p.m. for afternoon delivery).

These rigid windows constrain the ability of truckers to make deliveries for two reasons: 1) arrivals after the intended window often result in a wasted trip or, at a minimum, loss of revenue, 2) because the limited hours are similar nationwide, they are extremely crowded. The competitiveness of the freight industry is such that customers will simply switch shippers if one fails repeatedly to deliver within the expected window.

If convenient parking locations near delivery points were readily available, truck drivers could conceivably drive to them and wait for the businesses to open. However, this is not the case. Poor accessibility to many delivery locations (e.g., lack of parking near ports or in the downtown financial district) exacerbates truckers' reliance on the highways to travel just in time for delivery at the point of destination.

For commodities moving by rail, travel time reliability is less of an issue. Many of the commodities are not very time-sensitive (e.g., coal, grain). The railroads themselves possess priority mechanisms to speed time-sensitive shipments along. For example, class I freight railroads in California typically abide by the following priority framework:

1. Priority intermodal (e.g., JB Hunt, Schneider, greater than 1,000 miles)
2. Commuter rail in urban areas
3. Inter-city trains (e.g., San Diegan, San Joaquin)
4. Freight trains from railroad
5. Freight trains from other railroads.

2.2.2 Data Availability

Transportation output data to develop the reliability performance indicators for highways include: inductive loop data supplying volume, speeds and distance between loops. Availability of data for truck movement will be the same as it is for automobile movement. This is useful for the applicability of reliability to trucks, since the majority of the distance traveled takes place over the interstate and state highway network. As with automobile travel, reliability data will be more available in urban areas than for rural areas.

With regards to rail, relevant data includes the actual travel time from origin to destination, which is routinely collected by the railroads, as well as the scheduled travel time.

2.2.3 Reliability Indicators

The indicator proposed for other modes (i.e., highway and transit) to represent reliability is the variability of trip time. The same indicator is proposed for freight movement. Variability of travel time will enhance the shippers' ability to schedule trips by providing a clear expectation of how long each trip should last for the segments located along a delivery route. In the near term, reliability of highway segments will be limited to those segments equipped with inductive loops.

The reliability indicator for freight rail is also the variability of trip time. Collecting scheduled and actual travel time representing one or more months of data may be somewhat challenging given the competitive nature of rail traffic.

2.2.4 Application of Indicators

The reliability indicator is applied as a monitoring, not a forecasting tool. The experience of monitoring over time may lead to the development of methodologies to forecast reliability.

In applying the reliability indicator to highways, Caltrans and regional agencies are in fact addressing the truck freight component since trucks and automobiles share the same right of way.

For rail freight, the application of the indicator will need to be calculated separately. The indicator is identical, however, as that for transit rail so the procedure will be familiar. The only potential challenge in applying the reliability indicator to freight rail is collecting travel time data from a private source, i.e., the railroads.

2.3 Mobility / Accessibility

Mobility / Accessibility was also listed as a key outcome to monitor for goods movement by the interviewees. This outcome is closely related to, and is helpful to monitor in tandem with, the reliability outcome.

2.3.1 Industry Perspective

Mobility addresses the ability to travel from the truck intermodal facility to the customer, the port to the truck intermodal facility, or from one rail yard to another, in a given time. Travel time and delay information are of interest to shippers for scheduling, routing, equipment utilization, shift assignment, overtime management reasons.

Truck drivers are interested in both recurrent and non-recurrent delay. For recurrent delay, no monitoring tools exist, so truckers rely on past experience or communication with other drivers. For non-recurrent delay, drivers rely on real-time incident reports such as radio broadcasts, Caltrans Transportation Management Center (TMC) changeable message signs, and CB messages from other truckers.

For freight rail, travel time is somewhat less important than it is for trucks, just like reliability is less important for rail than it is for trucks. However, travel time still is valuable to monitor, especially when 1) the travel time helps with equipment/crew optimization and 2) for medium haul trips where rail is competitive with trucks.

Accessibility is significantly more complex. Within the goods movement context, we mean access to parking (at or near delivery locations), to time of day accessibility to customer locations, and access to intermodal facilities:

- Parking is a particularly important issue in cities where many deliveries occur in the early morning rush hour
- Time of day issues are dependent on business hours, and in some cases ultimately on union agreements such as in the case of major port facilities
- Accessibility and circulation to intermodal freight facilities is important for regional (inbound traffic) and inter-regional travel (outbound traffic).

Accessibility of intermodal freight facilities to both the rail and highway networks is a critical link for freight firms. These facilities are strategically built by railroads near the interstate or state road network, generally on inexpensive land. They also occasionally include private road access.

2.3.2 Data Availability

Travel time data for truck traffic is measured the same way as for automobile traffic. Rural travel time data is limited especially for trucks due to the lack of loops, however.

Most of the fields required for accessibility will be available through a combination of existing Caltrans databases (e.g., roadside staging areas) and research of intermodal facilities (e.g., port truck capacity, rail access, and staging locations for trucks and rail cars).

2.3.3 Mobility / Accessibility Indicators

Broadly speaking, mobility can be seen as a line analysis function (i.e., segment based), while accessibility can be seen as a point analysis function.

The mobility indicators for goods movement are travel time and delay (lost time due to congestion). The methodology builds on research developed for the highway[7] and the transit modes[8].

7 *Applicability of Indicators to Highways*, *Booz Allen & Hamilton, June 1999*

8 *Applicability of Indicators to Transit*, *Booz Allen & Hamilton, June 1999*

For accessibility, the indicator can be based on the accessibility indicator developed for the transit system (e.g., demographics within a distance from transit stops). The most promising area for accessibility is developing Geographic Information System (GIS)-based maps showing staging areas for trucks / rail cars near primary destinations (e.g., ports, downtown areas).

Demographics within a certain distance from an intermodal facility is of limited interest for goods movement, however. GIS will provide a clean map for each intermodal facility. In addition, the GIS rings (e.g., 1 mile, 5 miles, 10 miles) can help gauge access to freeways and major arterials. The maps can be further enhanced with a time of day legend. Other options include adding the number of lanes and road condition.

2.3.4 Application of Indicators

Travel times and delay figures experienced by truck drivers in California are the same as for normal commuters. Caltrans and regional agencies can apply the two mobility indicators – travel time and delay (lost time) – in a manner that encompasses freight movement by extending the travel time and delay calculations already performed for the highway. With respect to forecasting, Caltrans and the regions will have to rely on travel demand model results, since they still provide the best source for speeds.

With respect to freight rail, travel time and delay are applied in the same manner as for rail transit. Again, data access from railroads may prove challenging and should be supported as part of current and future project outreach efforts.

Applying the accessibility indicator will help Caltrans and the regions monitor the state of accessibility of intermodal facilities and large destination centers to trucks and railroads.

Initially each of these indicators should be used as a monitoring tool. With time and the knowledge of highway / facility improvements, these indicators can be used as a forecasting tool as well.

2.4 Equity

In the Phase I of the Transportation System Performance Measures initiative, equity is defined as the *fair distribution of benefits and burdens*. The discussion further submits that transportation investments should be made so they be considered “fair” by a disinterested or objective observer.

The equity outcome has not been researched the same extent as other outcomes such as reliability and environmental quality. It is also controversial. The following discussion, therefore, reflects preliminary ideas on how the indicator(s) for equity can be applied to goods movement.

Equity was listed as important for goods movement in several interviews held. The main issue in equity as it relates to goods movement is how State funds are applied to goods movement improvement projects. One important concern seems to be the urban / rural split, where it is perceived that metropolitan regions receive a disproportionate share of the goods movement projects. Other concerns expressed include:

- An investment of public dollars into one mode will put another non-funded mode(s) at a competitive disadvantage

- How does one handle investments of public dollars for goods movement improvements versus person movement improvements.

2.4.1 Industry Perspective

Important goods movement functions take place in rural areas. Most notable among these functions is the farming industry:

- California's 1996 gross cash farm receipts (including farm-related services) were $22 billion, or 9.5 percent of the state's total annual income[9]

- California farming industry exports for 1996 were estimated at $7.3 billion (farm gate value)

- Agriculture supports 1.4 million jobs in California, accounting for nearly 10 percent of all employment

- Southern California, although heavily urbanized, has twice the farm-related employment of any other region with 120,000 jobs supported by agriculture.

The issue at stake here is good truck and railroad access to fields and centers of agriculture production and distribution. In California, this applies to the whole central valley from Bakersfield to Redding. In addition, there are other regions in the state which face a competitive disadvantage with regards to attracting shippers (both trucks and railroads) due to their relative isolation or imbalance in import/export flows.

The Case of Humboldt County

There has been a perception that Humboldt county is "discriminated" against by the trucking industry due to its relatively isolated location. Trucks have restricted entry on US-101, SR 199, and SR 299 from the South, North and East respectively due to

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9 *Sources: The Measure of California Agriculture: Its Impact on the State Economy, University of California, and Bank of America reports*

highway curvatures. The steep curvature prevents trucks pulling 53-foot trailers, for example, from accessing the region.

For trucking companies delivering in Humboldt County, there is not much of an opportunity for back-haul (i.e., hauling a full truck back to the point of origination) given the region imports significantly more than it exports. This results in inflated shipping fees for Humboldt County customers since the trucking firms need to offset the empty returns. In addition, the market does not support many Less than Truckload (LTL) carriers, which also limits the choice of carrier for customers.

Finally, the only freight railroad in the region has been out of service for 18 months, further compounding the lack of competition in shipping. The publicly owned Northwestern Pacific has shut down due to financial troubles. Shippers cannot currently export over-dimensional loads (e.g., long redwood logs).

Potential highway straightening projects face environmental pressures due to the Natural Forests nearby. The equity issues facing Humboldt County are clearly multi-faceted, involving highway vs. rail issues, and econonic growth vs. environmental conservation issues.

Other Factors in Equity

One additional equity concern expressed by interviewees is access to intermodal facilities, particularly to ports. All shippers want good access to such facilities, not just big trucking concerns, but other smaller competitors also. In similar fashion, smaller short line railroads desire equal access. Given that Class I railroads, rather than short-lines, typically handle port traffic, they have the most access and are likely to be the ones responsible for handling other railroad equipment and car loads in timely fashion.

From a big picture perspective, it is important to understand how well the goods movement system is working. If the system is not working due to inequities in access to ports, Caltrans should know about the causes of the inequities so as to have the background necessary in formulating a solution. Note, however, that part of this issue is already being addressed in the mobility / accessibility outcome.

As mentioned before, other equity factors include equity between modes, and equity between goods and person movement projects.

2.4.2 Data Availability

Basic “goods movement” project information must be available to calculate equity indicators. The basic statistics necessary for the performance measures are produced for each project as part of the programming process and include project cost, number of lanes, lane-miles, and track miles. Travel time savings can also be calculated based on the delay indicator for mobility.

2.4.3 Equity Indicators

The proposed indicator for equity is the "*income group share of mobility benefits*". The Phase I report suggested using the distribution of forecast benefits in time saved, by income quintile. The distribution of benefits could also be compared to project improvement expenditures.

The income group share of mobility benefits indicator should be fully tested in the context of the performance measure initiative. It is recognized that costs do not equate to benefits. The cost analysis will be accounted for with the cost effectiveness outcome.

Urbanized / Rural Equity Example

The following examines options for addressing equity for urbanized vs. rural goods improvement projects. This can be accomplished either through a straight percentage or combination percentage, time savings, lane-miles (track-miles) of construction and dollars spent. In addition, the equity indicators will benefit from a complete description of the population / area served. As such the urban / rural split can be tracked at regular intervals. This indicator is based on the proposed indicator listed in the Phase I report - the income group share of mobility benefits.

One way the indicator could be calculated is shown in the following example. Currently, the Southern California Association of Governments is exploring truck-only lanes. Preliminary figures describing these new facilities suggest that most of the improvements will take place in urban areas. The time savings produced by the mobility improvements will be calculated by using the mobility indicator of delay, and may or may not correspond to the proportion of funds expended in the urban or rural area.

Facility	Length (miles)	Approximate Urban/Rural Split	Cost	Time Savings	Equity Indicator: Urban Benefit	Equity Indicator: Rural Benefit
SR 60	36	80 / 20	$$1	A Hrs Urban B Hrs Non-Urb.	A Hrs	B Hrs
I-15	34	50 / 50	$$2	C Hrs Urban D Hrs Non-Urb.	C Hrs 2	D Hrs
I-710	25	100 / 0	$$3	E Hrs Urban F Hrs Non-Urb.	E Hrs	F Hrs
I-5	44	100 / 0	$$4	G Hrs Urban H Hrs Non-Urb.	G Hrs	H Hrs

This example is somewhat simplistic and meant for illustration purposes. In applying this indicator, the urban and rural definitions could be fine-tuned.

2.4.4 Application of Indicators

The total amount of funds annually programmed by Caltrans applied to exclusively goods movement improvement projects is small compared to transportation improvements in general. However, Caltrans and its regional partners would benefit from monitoring how equitably freight related improvement project funds are applied.

The equity indicator can be used for forecasting as well to the extent that project details in the STIP enable the calculation (or estimation) of time savings. Regions are already monitoring the progressive enlargement of urban development rings. This information needs to be incorporated into forecast calculations.

Finally, the discussion on equity needs to be enlarged to account for the differences in views of the context in which equity should be addressed: urban vs. rural, mode vs. mode, and goods movement vs. person movement.

2.5 Economic Well-Being

The fundamental business of private freight carriers is transportation. Improvement projects that facilitate goods movement directly impact their individual economic well-being, and as a primary sector of the economy, improvements in goods movement help the general economy. The general indicators developed for measuring economic well-being already incorporate goods movement. It is possible to use the same indicators to focus on goods movement. As with general performance measurement, economic well-being measures are better suited for forecasting than for monitoring.

2.5.1 Industry Perspective

Transportation projects can improve goods movement by adding truck-only lanes that allow shippers to by-pass congestion, by building facilities that link railways with ports, by constructing ramps that connect highways with intermodal facilities, by improving railways, or other such projects.

While these improvements clearly affect mobility / accessibility, reliability, or even safety, they also impact a firm's bottom line. The effect can be positive or negative. A facility that links railways with maritime ports helps both railroads and shipping companies, but the gain may be at the expense of trucking companies. In assessing the impact of transportation improvements on firms and the economy, it is important to determine whether the result is a net benefit, or merely a transfer of benefits.

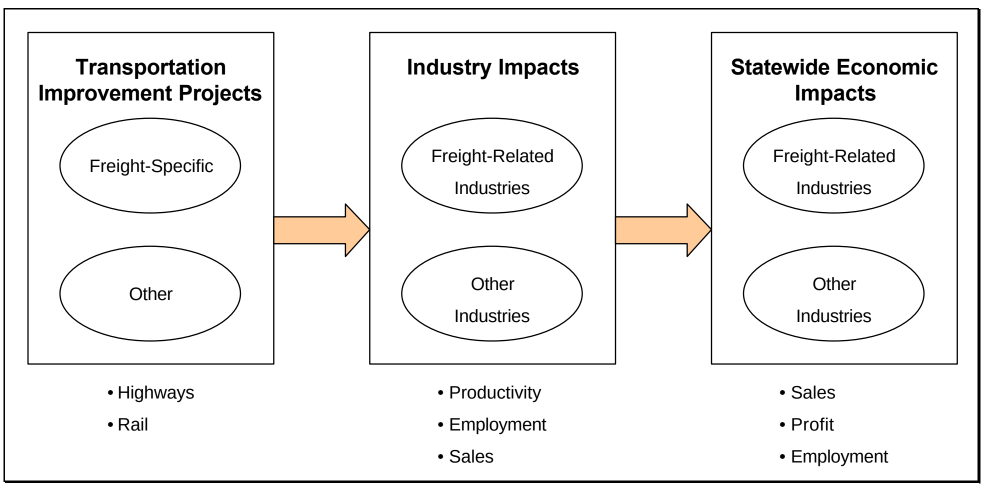
Goods movement projects can increase freight productivity by:

- Lowering travel costs
- Improving logistics through better routing
- Creating economies of scale by increasing the market reach of freight carriers.

Higher freight productivity may translate into increases in freight revenues, profits, and / or employment.

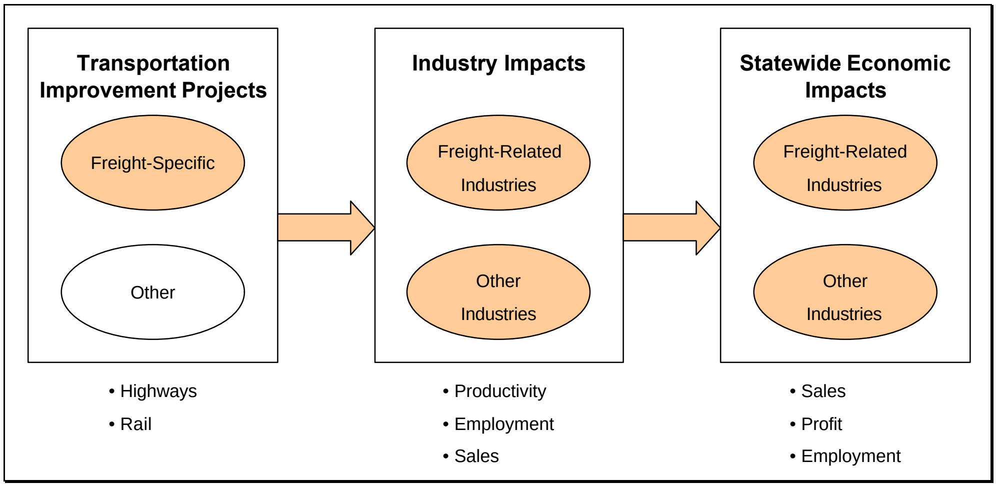
The benefits are not limited to just freight and shippers. More efficient (faster, better, cheaper) freight transport can lead to productivity increases in other industries through lower travel costs, improved logistics, or economies of scale. Also, the growth in shipping may increase employment in freight industries. The growth in employment generates demand for housing, food, clothing, and other consumer products. By helping both freight and non-freight industries, goods movement projects benefit the general economy through higher sales, profits, and employment.

In addition, freight-related industries may benefit from improvement projects that do not focus on goods movement. For instance, a lane addition project intended to relieve congestion along a key commute corridor may facilitate goods movement along the same corridor. As illustrated below, these effects are felt by all industries, freight-related or not.

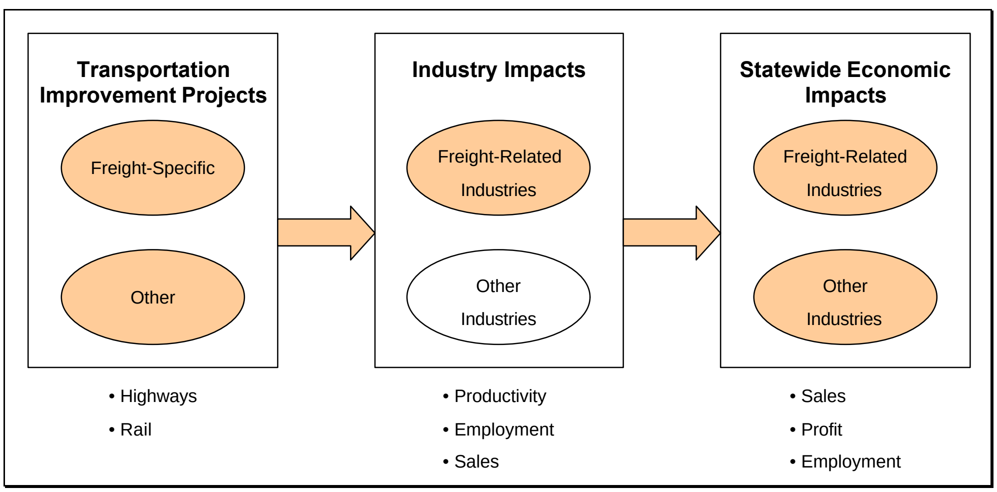


Goods movement benefits economically from transportation projects and the economy benefits from goods movement. However, identifying an appropriate indicator of economic well-being for goods movement requires us to consider what aspect of goods movement we mean.

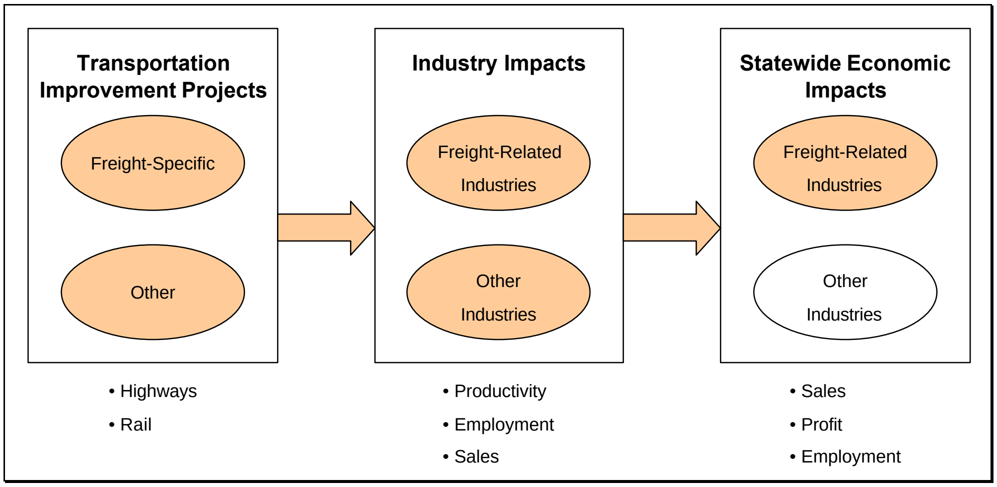
- *Option 1 - Do we mean transportation projects that are intended primarily to facilitate goods movement?* In this case, we focus only on the economic impact of projects directed towards improving goods movement, such as trucking lanes. The economic well-being impact of projects not targeted specifically to facilitating goods movement, such as standard lane addition projects, are ignored even if they impact goods movement.



- *Option 2 - Do we mean the impact of freight transportation alone on the total economy?* As an intended consequence or not, many transportation projects impact goods movement. If goods movement is improved, freight-related industries (e.g., trucking and railroads) benefit through higher profits, employment, and sales. Since these industries (and their employees) must spend their good fortune somewhere, the economy as a whole benefits. As illustrated in the figure below, this approach ignores changes in productivity for other industries, construction spending, tourism impacts, amenity increases due to travel time savings, and other direct consequences in non-freight related industries.



- *Option 3 - Do we mean the economic impact of transportation projects on freight-related industries only?* By facilitating goods movement, transportation projects benefit freight-related industries by lowering their production costs. Freight-related industries may also benefit from a greater demand for goods movement due to increased sales and productivity improvements in other industries. As illustrated in the figure below, this option ignores economic impacts, such as increases in employment or sales, in non-freight industries. In-house goods movement (e.g., the movement of lumber by a logging company using its own trucks) may be omitted.



Option 3 is probably the most appropriate option for measuring the economic well-being in goods movement. Like other outcomes discussed earlier (such as reliability) this option focuses specifically on the impact for freight-related industries. Option 2 focuses on the impact of these industries on the general economy. Option 1 ignores the unintended impact of many transportation projects on good movement.

2.5.2 Data Availability

Data are widely available on economic activity in California. Both local, state, and federal agencies collect and publish information on general economic measures such as:

- Personal income
- Number of households
- Employment by industry
- Revenues
- Value added.

The Economic Research Unit at the California Department of Finance publishes annually the California Statistical Abstract, which provides many measures on the health of the California economy, such as employment, wages and gross state product.

For goods movement, employment, revenue, and value added are probably the most relevant economic data, although changes in personal income are arguably also important to economic well-being. Which industries to examine and at what level depend on how the impact of goods movement is measured (i.e., impacts on freight industries or impacts by goods movement on the total economy).

Regardless of the choice, ample current and historic data are available. The United States Census Bureau collects detailed information on employment and revenues by industry as part of its periodic Economic Censuses. The Census Bureau also collects annual employment by industry and county in its County Business Patterns series of publications. The California Trucking Association in conjunction with the Western Highway Institute has compiled statistics about the economic condition and impact of the California trucking industry.

Several other sources exist for forecasts of future economic conditions. Private firms, such as the WEFA Group and DRI/McGraw Hill, predict changes in gross state/regional product and employment by sector. The UCLA Anderson Forecast provides long-term economic projections for the State of California and the nation, but it does not forecast the impact of specific projects. At the state level, UCLA forecasts changes in personal income, employment by industry, unemployment rates, population and migration, and construction activity.

However, neither current data nor forecasts tie economic well-being to specific transportation projects or groups of projects. Historical information on trucking employment does not measure the impact of building the Interstate highway system or any of its components. Trucking employment projections for Southern California by the Anderson Forecast do not take into account the impact of a potential network of truck only lanes.

Project Study Reports (PSRs) examine the impact of projects on the environment and traffic conditions, but generally ignore impacts on goods movement and the economy. For instance, PSRs do not forecast changes in gross regional product due to a transportation project. One economic modeling organization, REMI, suggests that the primary economic gains due to transportation projects occur through improvements in freight and goods movement.

The US Bureau of Transportation Statistics (BTS) includes several tables in its annual publication, *National Transportation Statistics*, related to goods movement and the economy:

- Contribution of Transportation Sectors to Gross Domestic Product (includes Trucking & Warehousing, Railroad, and Water as separate categories)

- US Gross Domestic Product Attributable to Transportation-Related Final Demand (freight not identified specifically)

- Per Capita Freight Statistics (e.g., Freight Tons Per Capita, Freight-Ton Miles Per Capita, and Freight-Ton Miles Per Dollar GDP).

While these data are aggregated at the national level, BTS collects sufficient data to allow similar statistics to be calculated at the State level.

BTS has also developed a series of “Transportation Satellite Accounts,” which identify goods movement within industries. Many industries perform their own goods movement rather than rely on trucking, rail, or maritime industries. For example, the logging industry uses its own trucks to haul lumber and the oil industry transports crude oil in its own ships. Standard freight measures ignore activities carried out in-house. The BTS satellite accounts can answer several questions about goods movement:

- How much do transportation services, including for-hire and in-house goods movement, contribute to Gross Domestic Product (GDP)?
- What industries rely on goods movement and what is its share of total production cost?
- What is the share of in-house and for-hire goods movement of final demand?

The BTS tables can be incorporated into standard economic models to measure the impact of goods movement, in-house and for-hire, on economic well-being.

2.5.3 Economic Well-Being Indicators

During the first phase of the transportation system performance measures project, the technical advisory group identified final demand as an appropriate indicator for measuring economic well-being. Final demand was defined as:

> *The value of all transportation-related goods and services, regardless of industry origin, delivered to the final customer, and includes consumer and government expenditures, investments and net exports.*

This general indicator can easily be applied to goods movement by measuring one of the following:

- Final demand generated by freight-specific projects (i.e, option 1),
- Final demand due to improvements in freight transportation (i.e., option 2), or
- Final demand only for freight-related industries (i.e., option 3).

2.5.4 Application of Indicators

Booz·Allen is currently exploring the use of the REMI regional economic model to measure final demand. REMI uses a combination of econometric, general equilibrium, and input-output techniques to model economic trends, productivity impacts, and interactions among industries. If the REMI model is applicable to measuring final demand in the performance measurement framework, our general economic indicator can be applied to goods movement

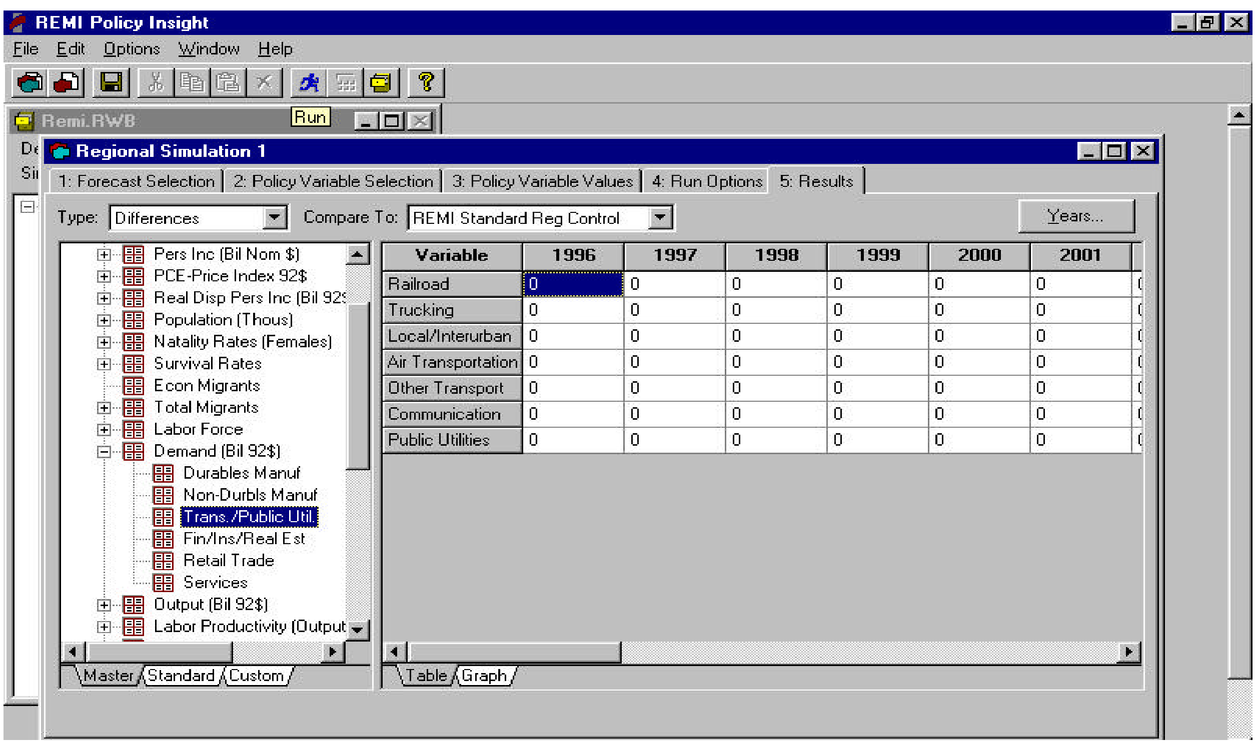
As discussed earlier, Option 3 is probably the most appropriate option for measuring the impact of transportation projects on economic well-being in goods movement. All transportation projects, freight-related or not, impact goods movement. Also, goods movement has measurable impacts on non-freight industries. Neither of these relationships should be ignored.

For performance measurement, the TASC proposed measuring final demand for transportation regardless of industry source. Option 3 can be implemented by measuring the final demand for goods movement transportation regardless of industry source. This measure is more appropriate for forecasting than monitoring.

REMI can measure the impact of transportation projects on final demand specific to freight-related industries. The model defines industries as detailed as the 3-digit Standard Industrial Code (SIC) level. Even the 2-digit level is sufficient to identify two primary freight industries:

- Railroad
- Trucking.

Air transportation may also be considered to the extent that it includes freight transportation. The figure below shows how REMI can break final demand into specific freight-related industries.



REMI is also capable of measuring economic well-being in goods movement using the definitions provided by the other two options. Booz Allen is currently exploring data requirements and model sensitivity.

2.6 Environmental Quality

One member of the System Measures Working Group recommended adding environmental quality as one of the outcomes applicable to goods movement.

2.6.1 Industry Perspective

Trucks make up a very small proportion of the overall highway market in terms of vehicles (about 4%), however they account for about 8% of total vehicle miles traveled[10]. Note that vehicle miles traveled (VMT) figures are based on actual counts from Caltrans[11].

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10 *Source: California Air Resources Board Motor Vehicle Emissions Inventory, 1996*

11 *CARB takes annual VMT figures directly from urban COGs. For non-urban areas, CARB relies on actual counts provided by Caltrans in the CMVSTAFF report. Annual VMT is taken from Caltrans document Truck Kilometers of Travel on California State Highway System. The point is that VMT and truck population forecasts are based on actual counts provided by Caltrans.*

Veh. Class	LDA	LDT	MDT	LHT	MHT	HHT	BUS	TOTAL	TRUCKS
Number of vehicles in use	15,515,392	6,465,253	847,346	486,240	213,558	181,178	6,104	**23,715,071**	880,976
% of TOTAL Veh	65.42%	27.26%	3.57%	2.05%	0.90%	0.76%	0.03%	**100%**	4%
VMT (000)	465,716	197,584	5,896	24,983	12,639	20,705	871	**748,394**	58,327
% of TOTAL VMT	62.23%	26.40%	3.46%	3.34%	1.69%	2.77%	0.12%	**100%**	8%

Where the vehicle classes are defined as follows:

LDA: Light Duty Automobiles
LDT: Trucks < 6,000 lbs
MDT: Trucks 6,001 to 8,500 lbs
LHT: Trucks 8,501 to 14,000 lbs
MHT: Trucks 14,001 to 33,000 lbs
HHT: Trucks > 33,000 lbs
BUS: Urban Diesel

Note that in the calculations only light heavy, medium heavy and heavy heavy trucks are considered for the truck definition.

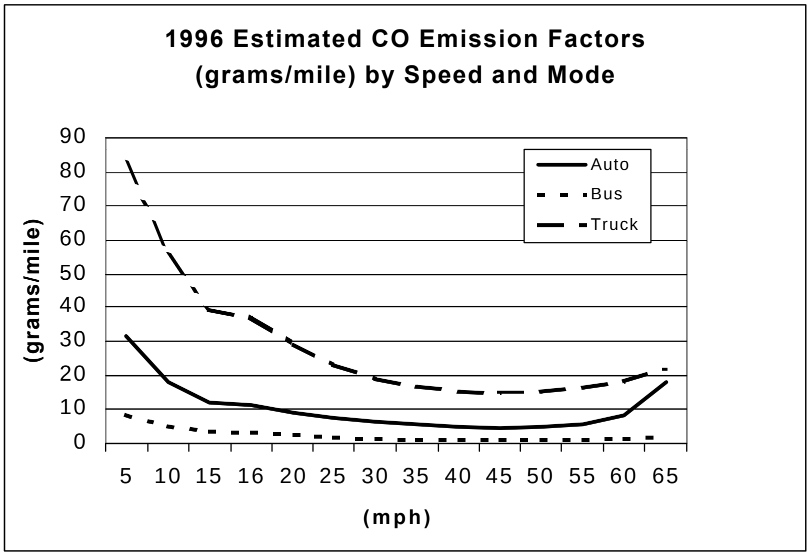
The overall proportion of truck VMTs is fairly stable and predicted to grow[12]:

YEAR	Light Duty Auto	Light Duty Truck	Medium Duty Truck	Light Heavy Truck	Medium Heavy Truck	Heavy Heavy Truck	Total Percent Truck
1997	71.9%	14.5%	5.1%	3.5%	2.4%	2.5%	8.5%
1998	71.8%	14.4%	5.2%	3.6%	2.4%	2.6%	8.6%
1999	71.7%	14.3%	5.3%	3.7%	2.4%	2.6%	8.7%
2000	71.6%	14.3%	5.3%	3.7%	2.4%	2.6%	8.7%
2001	71.6%	14.3%	5.4%	3.8%	2.4%	2.6%	8.8%

Finally, the emissions themselves tend to be higher for trucks than they are for autos or bus. This is true particularly for Carbon Monoxide (CO) and particulate matter (i.e., exhaust, break wear, tire wear). The exhibit below shows the relationship between speed traveled and CO emissions for trucks (the dashed line at the top), and autos and buses[13]. Note that truck CO emissions are significantly higher than for the other two modes at any speed traveled.

12 *Source: California Motor Vehicle Stock, Travel and Fuel Forecast, Caltrans TSIP, November 1998, page 25, and Booz Allen analysis*

13 *Source: California Air Resources Board Motor Vehicle Emissions Inventory, 1996*



Freight rail emissions are more difficult to tackle, primarily because rail emissions are not modeled by the California Air Resources Board on a consistent basis although it does provide some locomotive emission factors.

Regulation of locomotive emissions takes place at the federal, not the State level. The Environmental Protection Agency (EPA), the responsible agency, recently passed locomotive emission standards. These, however, are not to be phased in until 2004. As a first step, the EPA developed a comprehensive emissions inventory for locomotive, available on their website.

2.6.2 Data Availability

The main data sources are the emission inventories produced by the California ARB for trucks and the EPA for locomotives.

Demand data regarding the number of vehicle miles traveled or number of track miles traveled is available through Caltrans and the Freight Rail Administration.

2.6.3 Environmental Quality Indicators

The environmental indicators for person movement are meant to be subsumed from those required for State (e.g., California Environmental Quality Act or CEQA) and Federal requirements. These would be simply repeated here for aggregation at the regional or state levels.

Many “low impact” transportation improvement projects (e.g., short lane widening) can qualify for a categorical exclusion or simple Environmental Assessment, where mandated reporting is greatly simplified.

Larger projects require a full Environmental Impact Study (EIS), with specific measures for areas such as mobile emissions, water quality, wildlife impacts, and so forth. Note that mobile emission indicators typically focus on the planned impact for emissions quantities (e.g., pounds per year).

2.6.4 Application of Indicators

It has been the intention of the performance measures advisory committee to use the same environmental indicators as those required by State and federal regulations. The State and the regions should tie in the mandated environmental reporting with the State of the System report for performance measures. A close partnership with the Environmental Program will benefit this effort.

With respect to monitoring and forecasting, it can be said that monitoring environmental quality can be implemented immediately for all projects requiring environmental reporting at the State or the federal levels. Forecasting can be phased in using forecasted emission rates from Emfac7 for trucks and future locomotive emission rates from the FRA. Forecasting will be more resource intensive since this is traditionally not part of the State and federal reporting.

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Economic Impacts – Review and Findings

Technical Memorandum

Booz·Allen & Hamilton Inc.

June 30, 1999

TABLE OF CONTENTS

BOOZ·ALLEN & HAMILTON INC. EXAMINED METHODS FOR MEASURING THE IMPACT OF TRANSPORTATION INVESTMENTS ON THE ECONOMIC WELL-BEING OF THE STATE

- The Transportation Assessment Steering Committee (TASC) defined economic well-being as contributing to California's economic growth. The TASC proposed measuring economic well-being in terms of final demand, which it defined as the value of all transportation-related goods and services, *regardless of industry origin*

- Booz·Allen researched three economic model frameworks to determine their suitability for measuring final demand, as defined by the TASC, and found that:

  - Forecasting models are useful for predicting changes in general economic indicators, but not for measuring economic impacts of transportation investments

  - Benefit/Cost models are suitable for measuring the cost-effectiveness of potential investments, but not for measuring their impacts on final demand

  - Regional models are the most suitable for measuring economic well-being, as they forecast economic impacts on the regional economy. These models focus on regional effects and economic relationships across industries

- Two commercially-available regional models (REMI and IMPLAN) were compared. REMI was found to be more suitable, since it models the multiplier effect of transportation investments on economic well-being (as measured by final demand), and accounts for increases in industrial productivity due to these investments

THE NEXT PAGE PROVIDES DETAILED FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

REGIONAL MODELS ARE THE MOST APPROPRIATE FRAMEWORK FOR MEASURING ECONOMIC WELL-BEING USING THE INDICATOR PROPOSED BY THE TASC

MODELS	FINDINGS	CONCLUSIONS	RECOMMENDATIONS
Forecasting	• Forecasting models are useful as broad predictors of changes in general economic indicators, such as unemployment and inflation • However, it is difficult to tailor forecasting models to specific investments	Forecasting provides useful predictions of future economic conditions, but cannot measure transportation system performance	• Evaluate other economic models for measuring economic well-being
Benefit/Cost	• Benefit/cost models can estimate many transportation impacts (e.g., travel times, operating costs, etc.) • However, benefit/cost models focus on direct benefits and costs, rather than impacts on the state or regional economy (e.g., gross state or regional product)	Benefit/cost models are more appropriate for measuring cost-effectiveness than economic well-being	• Evaluate other economic models for measuring economic well-being • Consider using benefit/cost models to measure cost effectiveness
Regional	• Regional models can analyze, through purchases and employment, the economic impact of transportation investments • However, these models cannot fully capture final demand if some transportation services and equipment manufacturing occur outside transportation-related industries	Regional models can forecast the impacts of transportation investment on the regional economy. REMI is more suitable than IMPLAN for measuring economic well-being	• Test the applicability of the REMI model for performance measurement

THE REMI REGIONAL MODEL IS CAPABLE OF MEASURING IMPACTS OF TRANSPORTATION PROJECTS ON ECONOMIC WELL-BEING DUE TO INVESTMENTS AND PRODUCTIVITY GAINS

REGIONAL MODEL	FINDINGS	CONCLUSIONS	RECOMMENDATIONS
IMPLAN	• IMPLAN is based upon an input-output framework. It considers direct, indirect, and "induced" effects by examining industry transactions • It can generate five measures of regional economic activity: – Value added – Total industry output – Personal income – Total income – Employment	IMPLAN can measure the multiplier effect of transportation investment on economic well-being, but <u>cannot</u> measure productivity gains	• Examine alternative regional input-output models
REMI	• REMI supplements input-output framework with econometric models, which account for business cycles and add flexibility in timing economic impacts • Users may change economic policy variables to simulate impacts of policy changes • REMI can be calibrated to regional and state economic conditions	REMI can measure the multiplier effect of transportation investment on economic well-being, and <u>can</u> measure productivity gains	• REMI is the most appropriate model for monitoring economic well-being • Conduct case studies to test REMI further for its use in performance measurement

IN PHASE I, THE TRANSPORTATION ASSESSMENT STEERING COMMITTEE (TASC) PROPOSED USING FINAL DEMAND TO MEASURE ECONOMIC WELL-BEING

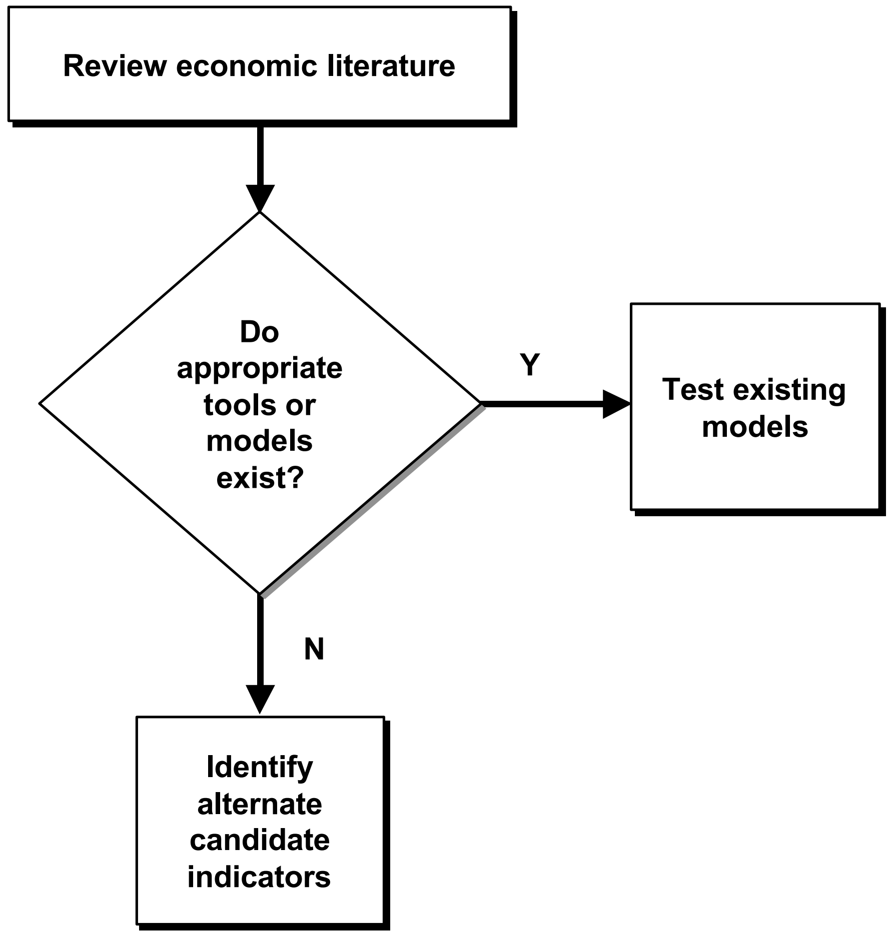
- Economic well-being was defined as contributing to California's economic growth
- The TASC defined final demand as the value of all transportation-related goods and services, *regardless of industry origin*
- The TASC proposed using regional input-output models as a potential methodology for measuring economic well-being

Phase I Recommendations

OUTCOME: ECONOMIC WELL-BEING	
Definition	Contributing to California's economic growth
Discussion	This outcome seeks to monitor the share of transportation-related final demand in gross regional (or State) product.
Candidate Measures	Final Demand

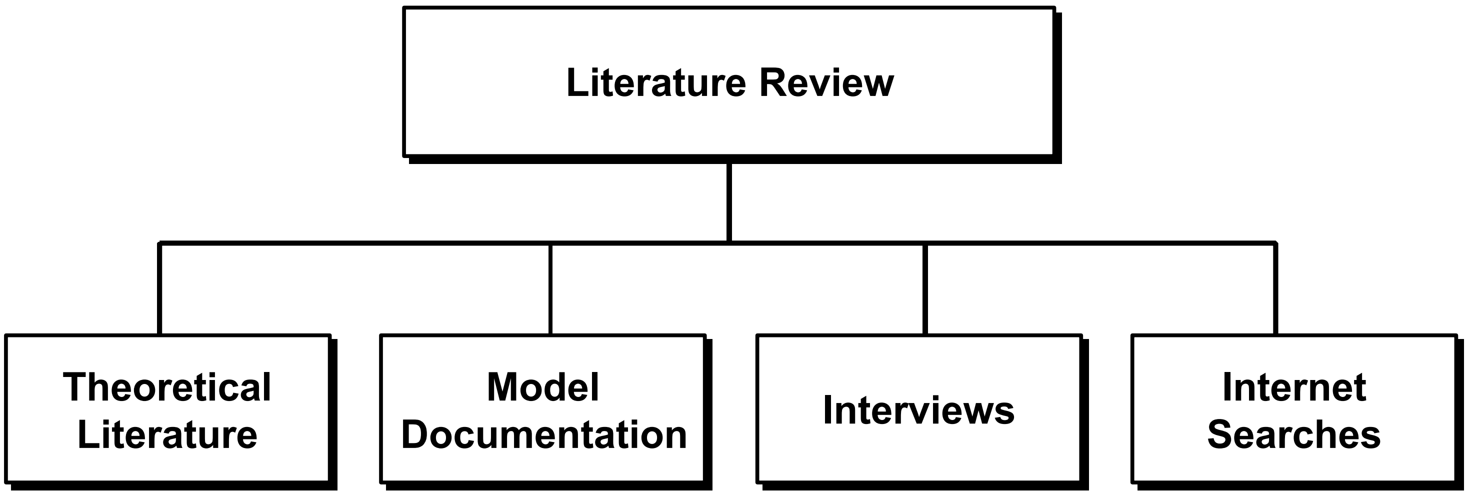
CANDIDATE MEASURES: FINAL DEMAND	
Definition	Final demand is the value of all transportation-related goods and services, regardless of industry origin, delivered to the final customer, and includes consumer and government expenditures, investments and net exports.
Discussion	The measure will be used to monitor changes in transportation-related economic activity. It will also show if the transportation share of economic production is rising, declining, or maintaining its current levels.

IN PHASE II, BOOZ·ALLEN FOLLOWED A TWO-TIER PROCESS FOR RESEARCHING CANDIDATE PERFORMANCE INDICATORS OF ECONOMIC WELL-BEING



IF APPROPRIATE TOOLS OR MODELS ARE FOUND, THEY WILL BE TESTED AS A LATER TASK

Components of Our Economic Literature Review



ECONOMIC PERFORMANCE INDICATORS ARE PRIMARILY APPROPRIATE FOR FORECASTING

- Policy makers tend to be interested in knowing the impact of policy decisions on the economy. For example, they may want to know what the impact of a highway project to relieve congestion is on regional productivity, employment, and gross area product

- Forecasting allows policy makers to assess potential economic impacts and select among alternatives

- As we will discuss, several tools exist to make these forecasts

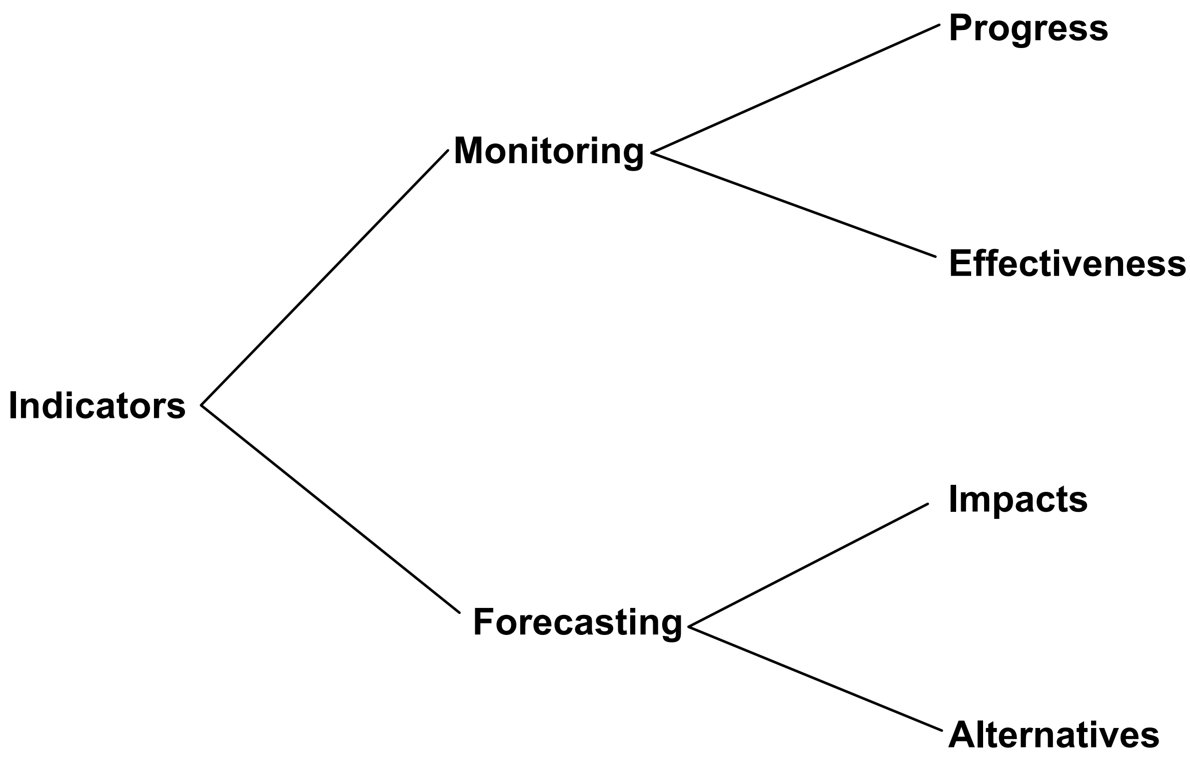
- However, it is difficult to monitor the progress achieved and the effectiveness of projects because many non-transportation factors influence the economy, such as:

  - External competition
  - New technology
  - Population growth
  - Change in consumer tastes

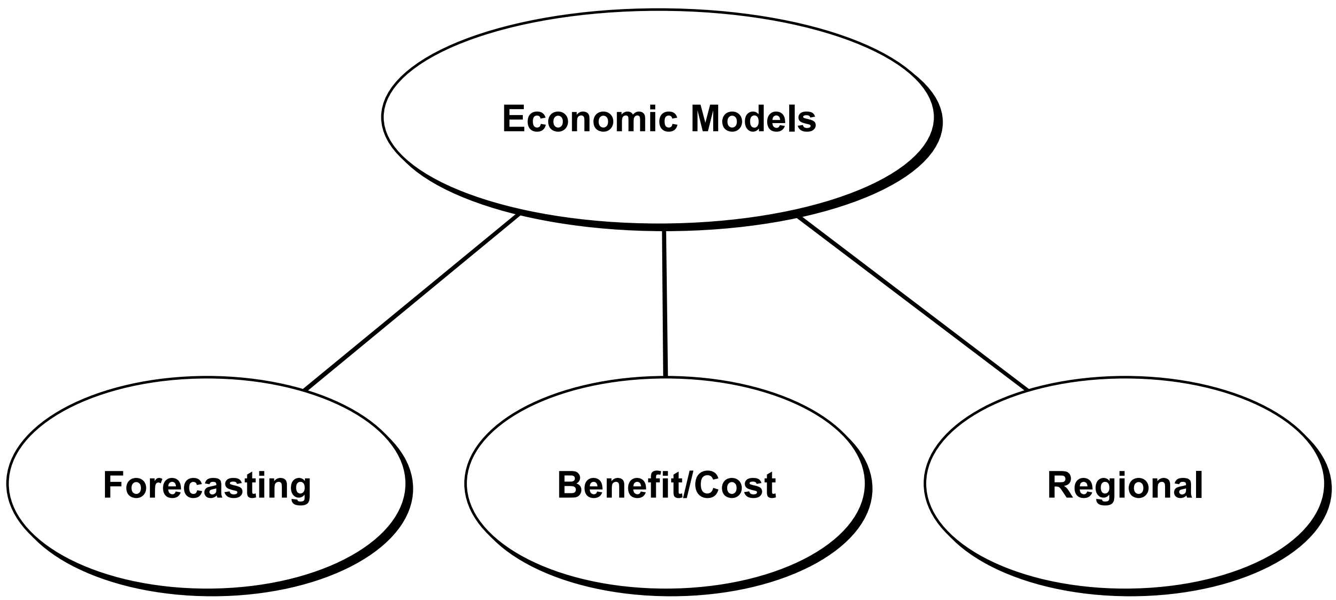
- Even if economic tools allow performance to be measured over time, the results are difficult to interpret

PERFORMANCE INDICATORS SHOULD NOT BE RELIED UPON FOR MONITORING THE IMPACT OF TRANSPORTATION ON ECONOMIC WELL-BEING

Potential Uses for Performance Indictors



OUR RESEARCH IDENTIFIED THREE CATEGORIES OF ECONOMIC MODELS OR TOOLS



IN THE SECTIONS THAT FOLLOW, WE DESCRIBE THE APPROPRIATENESS OF EACH CATEGORY FOR MEASURING IMPACTS ON ECONOMIC WELL-BEING

Forecasting

- DRI / McGraw-Hill
- WEFA Group
- UCLA
- ValueLine

Benefit/Cost

- STEAM
- RailDec
- Caltrans LCBM
- StratBENCOST
- HERS

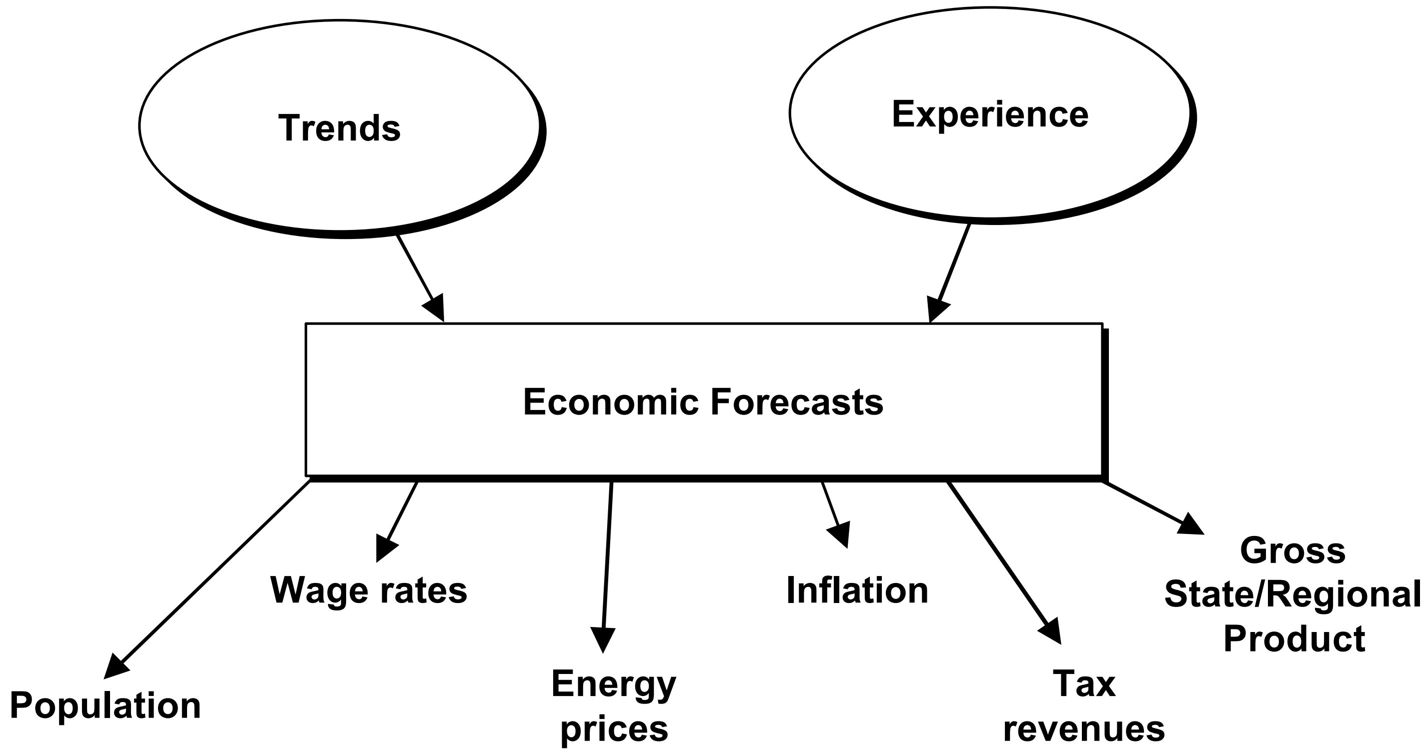
Regional

- IMPLAN
- REMI

SEVERAL ORGANIZATIONS USE TRENDS AND MACROECONOMIC RELATIONSHIPS TO FORECAST FUTURE ECONOMIC VALUES

- Public and private agencies routinely make economic forecasts:
  - Government agencies (e.g., Bureau of Economic Analysis, Association of Bay Area Governments - ABAG)
  - Private organizations (e.g., DRI/McGraw-Hill, ValueLine, WEFA Group)
  - Universities (e.g., UCLA)
- While some forecasts focus on the performance of specific businesses or sectors of the economy, most predict changes in general economic indicators, such as employment or gross state/regional product
- Forecasts are useful as general predictors, but are hard to tailor to specific investments
- Some private firms conduct special analyses to capture the effects of specific programs or projects. For example, DRI/McGraw-Hill examined the impact of environmental and energy considerations on highway policy for the Federal Highway Administration (FHWA). However, custom estimates are costly, time consuming, and frequently not comparable across projects
- A series of forecasts may help in monitoring, but separating the effects of specific projects from general changes in the economy is difficult

ECONOMIC FORECASTS ARE NOT APPROPRIATE FOR MEASURING ECONOMIC WELL-BEING


Trends
Experience
Economic Forecasts
Population
Wage rates
Energy prices
Inflation
Tax revenues
Gross State/Regional Product

BENEFIT-COST MODELING IS AN EMERGING TREND IN TRANSPORTATION

- Benefit-cost models have been implemented at Caltrans (i.e., Life-Cycle/Benefit-Cost Model) and other organizations

- These models focus on forecasting and evaluating project/program impacts rather than monitoring progress

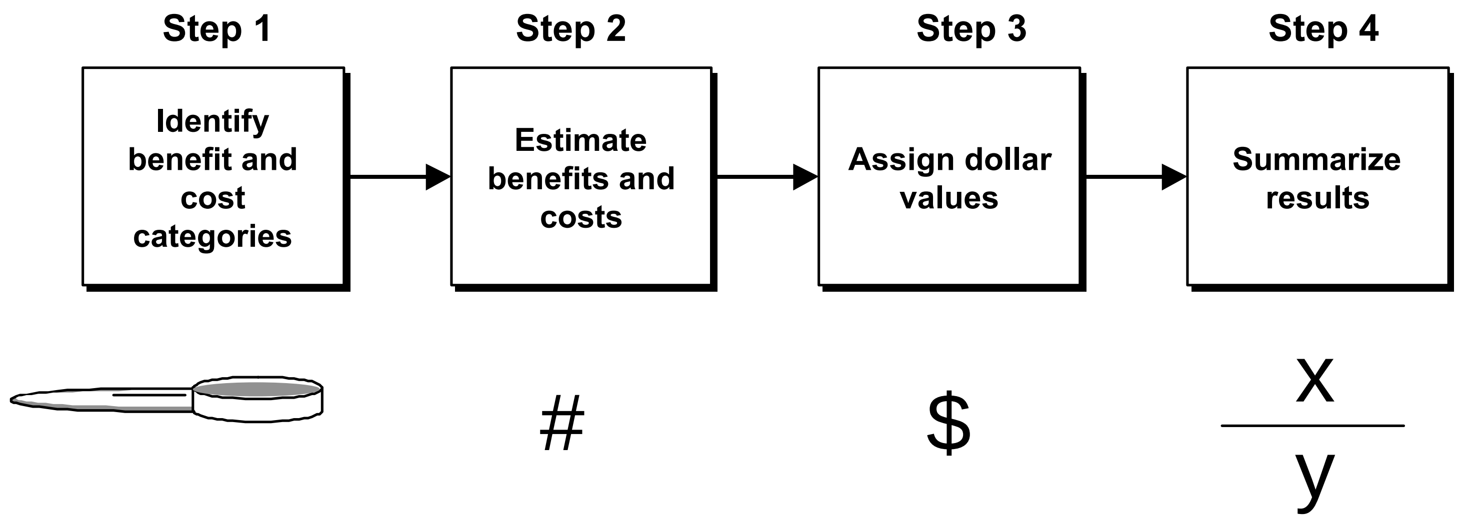
- Dollar values are assigned to all impacts, including externalities (e.g., air pollution)

- After valuing all impacts, benefit/cost models produce a summary statistic such as:

  - Benefit-cost ratio (compares benefits to costs)
  - Internal rate of return (shows the return on investment)
  - Net present value (assesses the value of the project)

- Assigning dollar values to some transportation benefits and costs can be difficult and controversial (e.g., value of life). As a result, some organizations choose to analyze cost-effectiveness ratios (e.g., lives saved per million dollars spent), rather than assign dollar values to each benefit and cost. This approach does not allow benefits to be summed and compared to costs comprehensively

Benefit-Cost Framework



WE EXAMINED THE CAPABILITIES OF SEVERAL COMPUTERIZED BENEFIT-COST MODELS

- Benefit/cost models can estimate many transportation impacts:

  - Travel times
  - Operating costs
  - Accident/safety costs
  - Social and environmental costs

- These models focus on *direct* benefits and costs, rather than changes in the economy. For instance, benefit/cost models are incapable of measuring changes in: industrial productivity, production processes, wages, goods prices, employment, market shares, or gross regional product

- Benefit/cost models may double-count outcomes measured by other performance indicators (e.g., mobility, environmental quality, safety, and security)

- Comprehensive models are very data intensive and external models, such as regional planning models, are sometimes required. Most computerized models focus on a single mode, since modeling multi-modal impacts requires estimates of demand and mode shift

BENEFIT/COST MODELS ARE MORE APPROPRIATE FOR MEASURING COST EFFECTIVENESS THAN ECONOMIC WELL-BEING

Benefit/Cost Models Examined

Model Attribute	HERS	Caltrans LCBM	RailDEC	StratBENCOST	STEAM
Model Complexity	Simple, built-in HPMS database	Medium, lookup tables	Medium, default national database	Complex, several inputs	Very complex, regional model required
Transportation Modes	Highway only	Highway & intercity rail separately	Rail, includes highway impacts	Highway only	Highway & transit
Impact Area	Short segment length, no cross impacts	Corridor only	Corridor only	Single segment or network	Network (corridor, if data formatted appropriately)
Peak Period	Annual ADT & effective speed, peak spread factor	Not considered, annual ADT	Not considered, annual ADT	Peak number of hours & percent of annual ADT, no peak spread	User defined
Operating Costs	Number of trips, travel distances, & speed	Annual VMT	Speed & grade	Road geometrics, peak & off-peak	Highway (fuel & non-fuel based) & transit
Accident/Safety Costs	Functional system	Annual VMT	Highway only	Peak & off-peak	Two highway classes
Social and Environmental Costs	Possible future revision	Not considered	Emissions	Emissions	Emissions, noise, global warming
New Trips	Future revision	Not considered	Not considered	Demand elasticity or regional model output	Regional model output

REGIONAL MODELS FOCUS ON ECONOMIC RELATIONSHIPS AMONG INDUSTRIES

- Regional economic models have been used to analyze transportation investments by several organizations, such as the South Coast Air Quality Management District (SCAQMD), Los Angeles County Metropolitan Transportation Authority (LACMTA), and Caltrans (for the ITMS project)

- An "input-output" framework forms the basis of most regional models. This framework assesses the economic impact of implementing a transportation project through purchases and employment. These impacts are driven by construction and investment

- Some regional models add components that assess the effect of transportation improvements on industry productivity. For example, the REMI model can show how travel-time savings effect regional productivity

- However, regional models may not be sensitive enough to measure the impact of individual projects (e.g., a transit project that affects only a single corridor)

- Also, these models can not fully measure the impact if some transportation services and equipment manufacturing occur outside transportation-related industries (e.g., a paper mill operates its own trucks)

WE EXAMINED TWO COMMERCIALLY-AVAILABLE, REGIONAL ECONOMIC MODELS – IMPLAN AND REMI

Commercially-Available Regional Models

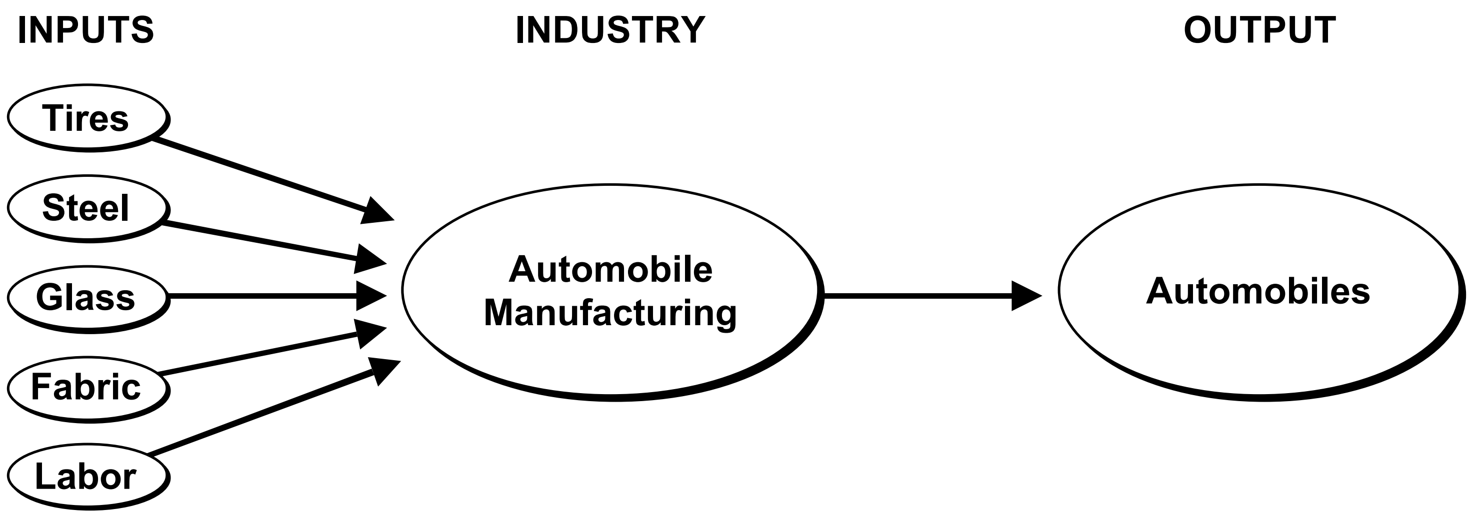
MODEL	MULTIPLIER EFFECTS	PRODUCTIVITY GAINS
IMPLAN	✓	✖
REMI	✓	✓

IMPLAN IS A BASIC, REGIONAL MODEL BASED UPON AN INPUT-OUTPUT FRAMEWORK

- IMPLAN considers direct, indirect, and "induced" effects by examining transactions among area industries
- Since information on regional transactions is limited, IMPLAN relies on national data. The model supplements this information with regional data, as available, at the county and state level. Industry activity is measured at the county, state, or national level using three-digit Standard Industrial Classification (SIC) codes
- The model captures "economic multiplier" effects (e.g., increases in construction employment, more money spent in the economy), but not productivity gains. For example, IMPLAN cannot measure productivity gains due to eliminating congestion in an area
- IMPLAN can generate five measures of regional economic activity:
  - *Value added*
  - Total industry output
  - Personal income
  - Total income
  - Employment

IMPLAN CAN MEASURE THE MULTIPLIER EFFECT OF INVESTMENT ON ECONOMIC WELL-BEING, BUT NOT PRODUCTIVITY GAINS

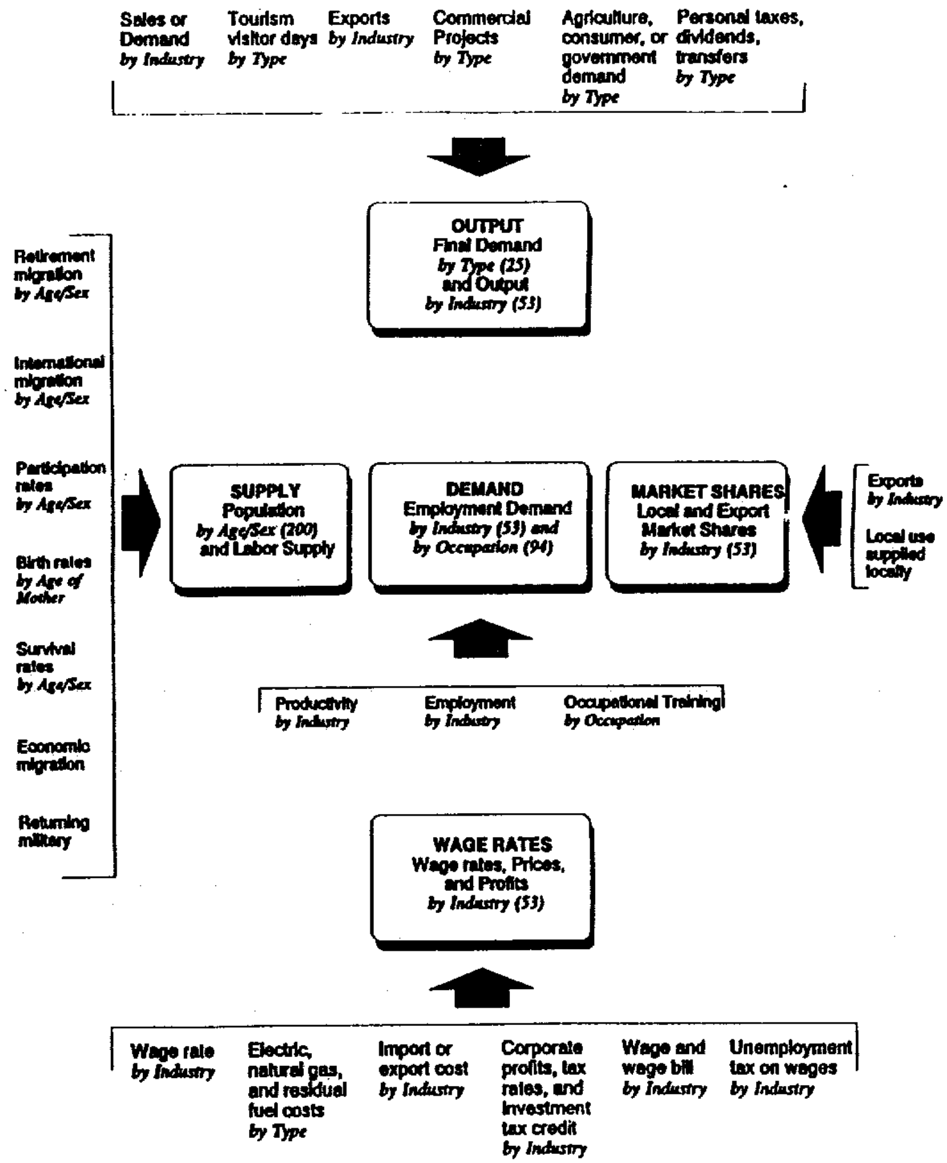
Example of a Regional Transaction



THE REMI MODEL ADDS THE ABILITY TO MEASURE PRODUCTIVITY GAINS

- The South Coast Air Quality Management District (SCAQMD), among others, uses REMI
- REMI supplements the basic input-output framework with econometric models of the economy. REMI accounts for business cycles and adds flexibility in timing economic impacts
- Users may change economic policy variables to simulate the impacts of policy changes and conduct what-if analyses
- The model can be calibrated to regional or state economic conditions
- REMI is proprietary and costly. Training classes are given semi-annually in California. Information on REMI is available at http://www.remi.com

REMI IS CAPABLE OF MEASURING THE IMPACT OF TRANSPORTATION PROJECTS ON ECONOMIC WELL-BEING DUE TO INVESTMENTS AND PRODUCTIVITY GAINS.



Source: Model Documentation for the REMI EDFS-53 Forecasting and Simulation Model

REGIONAL MODELS APPEAR TO BE THE MOST APPROPRIATE FRAMEWORK FOR MEASURING ECONOMIC WELL-BEING

- *Economic forecasting* provides useful predictions of future economic conditions, but it cannot measure transportation system performance

- *Benefit/cost models* are more appropriate for measuring cost effectiveness than economic well-being. Some caveats apply:

  - These models may double-count outcomes measured by other performance indicators (e.g., mobility, environmental quality, safety and security)

  - Some benefits are hard to convert to dollar values

- *Regional models* can forecast the impacts of transportation systems on the regional economy. However:

  - Regional models may not be sensitive enough to measure the impact of some individual projects

  - These models can not fully capture final demand if some transportation services and equipment manufacturing occur outside transportation-related industries

APPROPRIATE MODELS EXIST FOR MEASURING ECONOMIC WELL-BEING

- Economic well-being measures are capable of periodic forecasting, but not on-going monitoring
- The candidate measure is the final demand for all transportation-related goods and services, regardless of industry origin
- Regional models measure final demand
  - IMPLAN and REMI model the multiplier effect of transportation investments on economic well-being
  - REMI also accounts for increases in industrial productivity due to transportation investments

AS A NEXT STEP, BOOZ·ALLEN SHOULD USE CASE STUDIES TO TEST THE APPLICABILITY OF REMI FOR MEASURING ECONOMIC WELL-BEING

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Economic Well-Being Test Results
Technical Memorandum

Booz·Allen & Hamilton Inc.
June 30, 1999

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EXECUTIVE SUMMARY

Economic well-being *can be measured* for transportation system performance. In the first phase of the Performance Measurement initiative, the Transportation Assessment Steering Committee (TASC) proposed measuring economic well-being to monitor the share of transportation-related final demand in the gross regional product at the state or regional level. The TASC defined economic well-being as "contributing to California's economic growth" and suggested a candidate measure, described as:

> *The value of all transportation-related goods and services, regardless of industry origin, delivered to the final customer, and includes consumer and government expenditures, investments and net exports.*

This definition leads to three potential indicators for measuring economic well-being:

- Gross Regional Product (GRP)
- Demand
- Output.

The TASC intended for the candidate measure to be used to track changes in transportation-related economic activity and to show whether the transportation share of economic production is rising, declining, or maintaining current levels.

Demand is closest in definition to the indicator defined by the TASC. Demand measures *the value of goods and services purchased within a region* (including imports) and can be calculated for several *transportation-related* industrial sectors:

- Motor Vehicle Manufacturing
- Rest of Transportation Manufacturing
- Petroleum Products
- Railroads
- Trucking
- Local/Interurban Transportation
- Air Transportation
- Other Transportation
- Automobile Repair Services.

These industrial classifications may not capture all of the regional purchases related to transportation (e.g., automobile insurance and in-house transportation), but most are covered. The total demand for these sectors approximates the transportation share of economic activity.

The demand indicator may be supplemented by two indicators – output and GRP, which measure production and the creation of economic value.

Other economic indicators, such as personal income and employment, measure aspects of economic well-being that directly concern California residents. Since these indicators do not match the definition of economic well-being provided by the TASC, they are not explored further in this report. However, these measures may be useful to include in the performance measurement framework.

The REMI Policy Insight Model is a regional economic model that measures transportation-related demand and forecasts changes in demand due to transportation improvement projects. Since REMI also generates the other two indicators on every run, all three should be presented to policy makers, who can decide which one(s) to use. In addition, REMI forecasts changes in other indicators related to economic well-being, such as personal income and employment.

As part of the testing conducted for this project, REMI was run for two hypothetical case studies. The case studies demonstrate that all three potential indicators (demand, output, GRP) are sensitive to the level of transportation investment. Analyzing individual projects probably makes more sense for local governments than for the State or regions. State and regions should focus on groups of transportation investments.

The following table summarizes the main findings, conclusions and recommendations relative to the testing completed for economic well-being.

OUTCOME	INDICATOR	FINDINGS AND CONCLUSIONS	RECOMMENDATIONS FOR IMPLEMENTATION
Economic Well-Being	Final Demand (i.e., GRP, demand, or output)	• The outcome can be measured by: - GRP - Demand - Output • REMI successfully estimates all three indicators • REMI also estimates other economic indicators, such as: - Personal income - Employment • The indicators are a tool for forecasting economic well-being, not monitoring	• Use all three indicators (i.e., GRP, demand, and output) to estimate economic well-being • Consider supplementing these indicators with others to capture different aspects of economic well-being: - Personal income - Employment • Analyze bundles of transportation investments at the State and regional level • Incorporate economic well-being forecasting results with other State-level forecasting baseline

1. INTRODUCTION

This document presents the findings for Task 4b of the current Performance Measurement initiative led by the California Department of Transportation (Caltrans). As part of this initiative, Booz·Allen & Hamilton was asked to test existing models and tools to demonstrate their applicability in measuring economic well-being for performance measurement.

In Task 4a, Booz·Allen reviewed the economic literature to determine if appropriate tools existed. Several models were examined, including forecasting, benefit-cost analysis, and regional models. Although forecasting provides useful predictions of future economic conditions, it was concluded that forecasting cannot measure transportation system performance. Task 4a also found that benefit/cost models are more appropriate for measuring cost effectiveness than economic well-being. Regional models were identified as the most appropriate framework for measuring economic well-being.

Two commercially-available, regional economic models were examined – IMPLAN and the REMI Policy Insight Model. IMPLAN is a basic, regional model that considers economic impacts by examining transactions among area industries. The REMI model adds the ability to measure productivity gains and allows users to change economic policy variables, such as the amenities available in a particular region. On the basis of this review, the REMI model was chosen for further testing for use in performance measurement.

This technical memorandum presents the results of that testing, interprets the results, and provides recommendations for future use.

The sections that follow describe:

- Potential indicators for measuring economic well-being
- Limits in monitoring economic well-being
- Inputs needed to measures the impact of transportation projects using REMI
- Results of two hypothetical case studies
- Findings and conclusions.

2. MEASURING ECONOMIC WELL-BEING

In the first phase of the Performance Measurement initiative, the Transportation Assessment Steering Committee (TASC) proposed measuring economic well-being to monitor the share of transportation-related final demand in the gross regional product at the state or regional level. The TASC defined economic well-being as "contributing to California's economic growth" and suggested a candidate measure, described as:

> *The value of all transportation-related goods and services, regardless of industry origin, delivered to the final customer, and includes consumer and government expenditures, investments and net exports.*

This definition suggests three potential indicators of economic well-being:

- Gross Regional Product (GRP)
- Demand
- Output.

These indicators differ by whether they consider where goods and services are **purchased**, where goods and services are **produced**, or where **value-added**[1] is created. As indicated in the final report for the first phase of the performance measurement initiative, the TASC intended for the candidate measure to be used to track changes in transportation-related economic activity and to show whether the transportation share of economic production is rising, declining, or maintaining current levels.

Demand has the closest definition to the indicator defined by the TASC. Demand measures *the value of goods and services purchased within a region* (including imports) and can be calculated for several *transportation-related* industrial sectors. The demand indicator can be supplemented by output and GRP, which measure production and the creation of economic value.

Other indicators, such as personal income and employment, measure aspects of economic well-being that directly concern California residents. While these indicators do not match the definition of economic well-being provided by the TASC, they may be useful to include in the performance measurement framework.

Table 1 highlights the advantages and disadvantages of the three primary indicators plus personal income and employment with regards to performance measurement.

The sections that follow discuss GRP, demand, and output, in more detail. The other two indicators are not explored further in this report, since they do not match the TASC definition of economic well-being.

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1 *Value added is the value of a firm's sales minus the value of the materials and other intermediate goods (and services) used in producing the goods (or services) sold.*

Table 1
Potential Economic Well-Being Indicators

Indicator	Definition	Advantages	Disadvantages
Gross Regional Product (GRP)	Total spending on goods & services produced within region	• Focuses on economic value generated in region • Measures general economic health of region	• Cannot measure the transportation demand directly • Must measure changes in total demand due to transportation improvements
Demand	Value of all goods & services purchased within region	• Measures regional demand for goods & services • Identifies transportation demand separately	• Includes imports, but excludes exports • Does not measure economic value generated in region
Output	Value of all goods & services produced within region	• Measures regional production, including exports • Identifies transportation demand separately	• Includes non-California consumers • Does not measure economic value generated in region
Personal Income	Total earnings from wages, passive enterprises, investment interest, and dividends for individuals in region	• Measures individual income • Captures effect of transportation on individual earnings	• Is not included in the TASC definition of economic well-being
Employment	Number of full-time and part-time employees in region	• Measures the number of jobs within region • Captures effect of transportation on employment	• Is not included in the TASC definition of economic well-being

2.1 Gross Regional Product

In standard economic textbooks, GRP is defined as total spending on goods and services produced within a particular region. GRP is the generic name for a measure associated with both states or regions (the notion being that relative to a country as a whole, states and metropolitan areas are simply regions).

Gross regional product is composed of four primary parts, which can be expressed in the following equation:

Gross Regional Product	=	Consumption
	+	Investment
	+	Government Purchases
	+	Net Exports (exports minus imports)

The components of this equation can be described as follows:

- Consumption is expenditures by consumers within the region on durable goods, non-durable goods, and services.

- Investment consists of fixed investment and inventories.

- Government purchases include all purchases of goods and services by all levels of government within the region.

- Net exports adjust for the fact that not all the goods and services bought within the region are produced within the region *and* not all goods produced within the region are bought within the region.

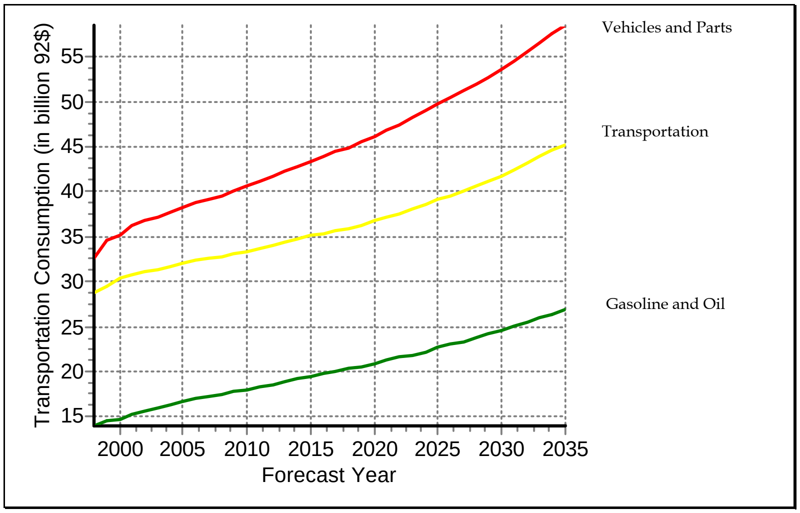
GRP is also equal to the sum of value-added generated within a region. The REMI model provides GRP forecasts in 1992 constant dollars. REMI forecasts the California GRP to be $997.1 billion (in 1992 dollars) for the Year 2000. The basis for all REMI runs tested is in nominal 1992 dollars.

The portion of GRP related to the consumption of transportation goods and services can be separated out of GRP. However, this measure includes only purchases by households (consumers). Government purchases, purchases by businesses (to produce other goods and services), and investment spending are excluded.

The impact of transportation investments on the region's economic health could be measured by the *change in GRP* due to the investments. However, this measure could only be used for forecasting the impact of specific projects not monitoring general economic well-being.

Exhibit 1 shows the portion of the California GRP related to household consumption of transportation goods and services. These figures were forecasted by REMI for 1998 to 2035 in 1992 dollars.

Exhibit 1
Transportation-Related Consumption in California GRP



Source: REMI Policy Insight Model

Adopting GRP as an indicator has advantages and disadvantages.

<u>Advantages</u>

GRP includes all goods and services produced within a region. Since it excludes the purchases of goods and services produced elsewhere, GRP focuses on the economic value generated inside the region. GRP measures the general economic health of the region.

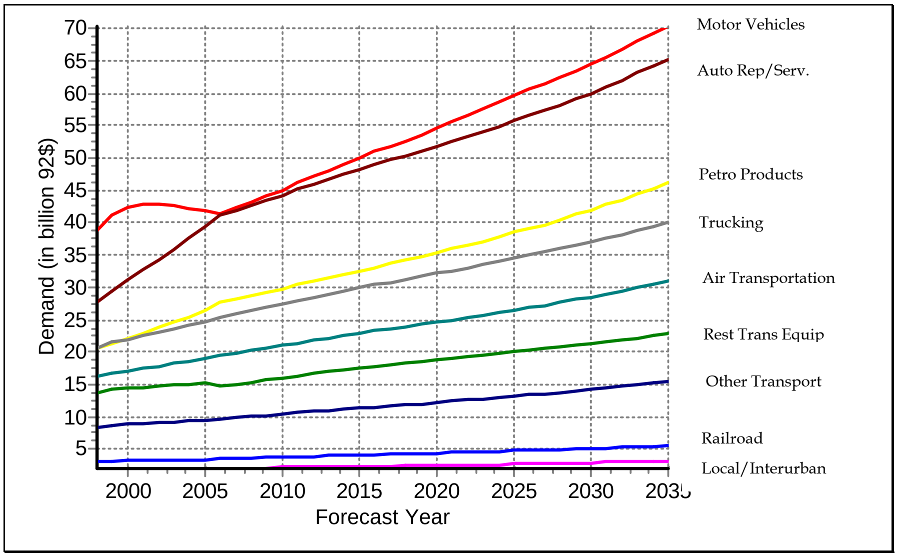
<u>Disadvantages</u>

The main disadvantage is that total GRP is not transportation-related and can be influenced by a variety of the other factors. As a result, GRP could be used for forecasting the impact of specific projects, but not monitoring. Transportation-related consumption can be identified separately, but this measure includes only purchases by consumers and ignores purchases by the government and businesses.

2.2 Demand

In macroeconomics, demand refers to the *value* of goods and services purchased by consumers and the government within a particular region (or the State). This indicator can be summed for the entire region or broken down by industry. REMI forecasts total demand in California to be $1,590.3 billion (in 1992 dollars) for the Year 2000. Of this amount, $163.2 billion is transportation-related demand. Exhibit 2 shows transportation-related demand (in 1992 dollars) for 1998 to 2035, as forecasted by REMI.

Exhibit 2
Demand in Transportation-Related Industries



Source: REMI Policy Insight Model

Adopting demand as an indicator of economic well-being has advantages and disadvantages.

<u>Advantages</u>

Demand measures the value of all goods and services purchased within a region, regardless of the purchaser. Both consumers and the government are included. Demand for the output of transportation-related industries can be separated from goods and services produced by other industries.

<u>Disadvantages</u>

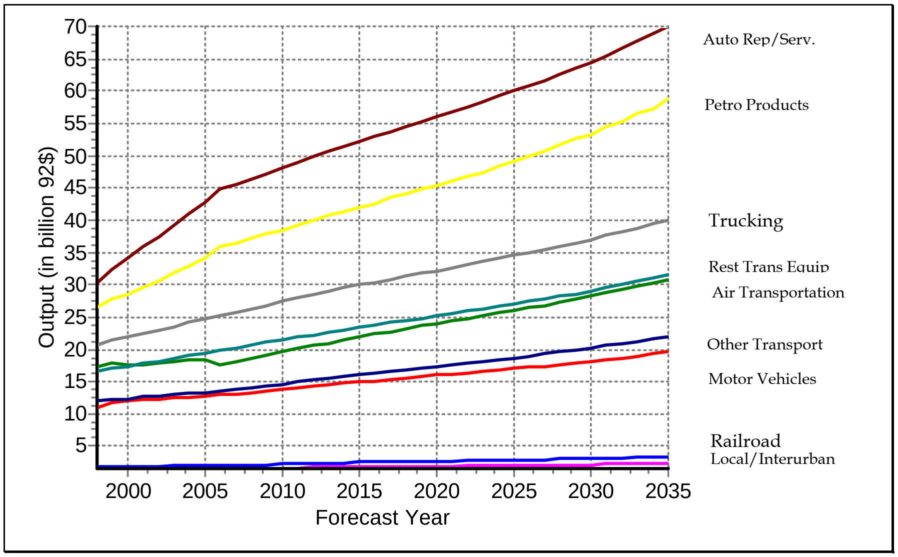
Regional demand can be satisfied by production originating from anywhere. For instance, the demand for automobiles in California may be met by a combination of California manufacturing and imports from other states and foreign countries. Also, demand does not capture economic activity generated within a region to meet external demand. For example, aircraft manufactured in California for export are not measured by demand.

Demand focuses on the value of what is demanded, but not where value is created during production. Even if demand by California consumers and the government is satisfied by California production alone (i.e., no imports to the state to meet demand), the economic value-added could be generated elsewhere, since producers may continue to import their intermediate goods and services.

2.3 Output

Output refers to the value of goods and services produced by the regional (or State) economy. Similar to demand, output can be summed for the entire region or broken down by industry. REMI forecasts the total output in California to be $1,545.3 billion (in 1992 dollars) for the Year 2000, as shown in Exhibit 3 on the following page. This is approximately $45 billion less that the equivalent figure for demand. Of total California output, $146.9 billion is transportation-related.

Exhibit 3
Output in Transportation-Related Industries



Source: REMI Policy Insight Model

Adopting output as an indicator of economic well-being has advantages and disadvantages.

<u>Advantages</u>

Output measures all production occurring within the region, including exports. Output can be identified separately for transportation-related industries, such as transportation equipment manufacturing, petroleum products, railroads, trucking, local/interurban transportation, and automobile repair services.

<u>Disadvantages</u>

The final customer for regional products and services can be located in the region or somewhere else. For example, automobiles manufactured by in the Bay Area can be purchased consumers and the government located in California or in other states.

While output measures the value of goods and services produced in California, output, like demand, does not capture where value is created during production. Although all output captured by this measure occurs in California, the value-added production could occur somewhere else.

3. FORECASTING ECONOMIC WELL-BEING

Regardless of which indicator is used, economic well-being is an outcome more appropriate for forecasting than for monitoring.

Transportation is only one of many sectors in the economy. State or regional economic well-being can be influenced by a variety of factors, which are not necessarily transportation-related. For instance, regional economic well-being may be effected by the health of the United States national economy, currency fluctuations, interest rates, wage rates, technological innovations, investments in other regions, and numerous other factors.

No method exists for separating the effects of transportation from these other factors when trying to monitor economic well-being. However, the impacts of transportation investments on economic well-being can be forecasted, assuming that all other factors stay constant.

4. REMI MODEL SIMULATIONS

The REMI model simulates the regional economy by using a combination of input-output, econometric, and general equilibrium techniques. REMI can be used to forecast the effect of a policy decision, such as investing in transportation infrastructure, by comparing the results of the policy forecast to those of the control forecast. Transportation professionals frequently refer to this type of comparison as a build/no-build comparison.

REMI builds its control forecasts by using annual data provided by a variety of sources, but the primary data comes from the Bureau of Economic Analysis (BEA) Regional Employment and Income Series. The most recent data available are for 1997 at the state level and 1996 at the sub-state level. REMI uses this historic data and economic relationships to forecast future economic conditions. These forecasts are compared to the University of Michigan's two-year, short-term forecasts and the BEA's output and employment forecasts by industry for 2006. Forecasts beyond 2006 are driven by U.S. Census projections.

By comparing the policy forecast to the "control" or base forecast, the REMI model can measure the changes due to policy decisions in several economic measures, including demand, output and GRP.

REMI constructs custom control forecasts for each model. Users can chose the level of industrial detail and the number of regions to include. A REMI model can simulate economic activity in 14, 53, or 142 industries. These options correspond roughly to one-digit, two-digit, and three-digit Standard Industrial Codes (SIC). Users may opt to have one or multiple regions modeled. If multiple regions are modeled, the impact of investment in one region on economic activity in another region can be measured. For example, a model that includes Northern and Southern California could show the impact of a transportation project in Southern California on the Northern California economy. Regions can be defined as states, counties, or aggregations of counties (e.g. Caltrans districts).

4.1 Measuring Transportation Project Impacts Using REMI

The REMI Policy Insight Model can be used to capture the effects of transportation infrastructure investments by measuring changes in seven critical areas:

- Construction and construction financing
- Public transportation
- Environmental impacts
- Tourism
- Cost savings for businesses
- Cost savings (including safety improvements) for consumers and commuters
- Economic impacts.

4.1.1 Construction

The effects of construction are handled simply by increasing spending in the construction industry by the amount of construction expenditures for the project. The financing of construction is modeled by changing tax rates or reducing government expenditures in other areas. Frequently, transportation projects are financed by outside sources (e.g. federal transportation allocations). Tax rate and government expenditure changes need to be adjusted by proportion of funds originating outside the region.

4.1.2 Public Transportation

For public transit projects, the operating impacts can be significant. The REMI model captures these effects by increasing employment in the appropriate economic sector (e.g., inter-urban transport), reducing consumer expenditures on other types of transportation, and increasing taxes to pay operating subsidies. As with construction financing, taxes are increased to pay operating subsidies only to the extent that local funding sources are used.

4.1.3 Environmental Impacts

Environmental effects are typically modeled by REMI as changes in local amenities (factors that effect quality of life). A reduction in, say, pollution will likely make the region more attractive to potential residents and lead to an increase in the labor pool, with corresponding effects on the local economy. Environmental impacts must be measured externally using a tool, such as the California Air Resources Board (CARB) Motor Vehicle Emissions Inventory (MVEI) or the Caltrans Life-Cycle/Benefit-Cost Model (LCBM).

4.1.4 Tourism

Tourism is a vital set of industries for California. The hotel industry alone generates output over $10 billion per year. Tourism effects are modeled through REMI by adjusting the number of tourists (measured in visitor-days) visiting the region. Tourists bring money into the region, which adds to local consumption. Simulating the effect of increased consumption requires an estimate of the distribution and amount of tourist expenditures by industry. REMI includes default tourist expenditures by industry based on research in Massachusetts. These expenditures can be changed if local tourism data are available.

4.1.5 Business Cost Savings

The effect of transportation investments on business costs depends on which transportation modes are being improved. Highway improvements reduce trucking costs, which increases productivity in the trucking industry. This effect is captured by a policy variable in REMI. In addition, some productivity gains need to be introduced for industries that supply their own in-house trucking.[2] Rail improvements reduce railroad costs and lead to productivity increases in the railroad industry. Few firms supply in-house rail transportation, so productivity does not need to be adjusted for other industries.

Transportation improvements that reduce travel costs also lower prices for regional industries. Travel cost reductions are different than other price reductions, because they apply equally to domestic production (production within the region) and imports. The model must be adjusted so that regional market shares do not change as a result of reduced prices. This adjustment is calculated by using the proportion of total cost due

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2 *As described later in this memorandum, the transportation satellite accounts developed jointly by the Bureau of Transportation Statistics and the Bureau of Economic Analysis, may help to assign these gains.*

to trucking for each industry, the percentage cost change in trucking, and the local market share elasticity.

4.1.6 Commuter Cost Savings

Cost savings occur for both commuters and other area residents. The cost reductions can be measured using a standard transportation benefit-cost model, such as the Highway Economic Requirements System (HERS) or the Caltrans LCBM. In these models, the cost reductions show up as benefits in accident costs, travel time, and vehicle operating cost. None of these savings are captured in the price indexes, and like environmental effects, are treated as amenity gains. The change in regional amenity increases the net number of migrants into the area, which has ramifications for the labor market and regional production.

4.1.7 Economic Impacts

The effect of transportation projects on the state or regional economy will vary by the type of project or bundle of projects. Inter-regional highway projects primarily impact the trucking industry by reducing shipping times and lowering operating costs. Reductions in travel times are particularly important to the trucking industry with the recent manufacturing trend of using just-in-time (JIT) delivery. Although commuters and recreational travelers may also be impacted, the economic effect tends to be small relative to the cost savings in the trucking industry.

Projects that focus on goods movement, such as intermodal shipment facilities, also tend to impact commercial transportation industries. For example, a project that facilitates ship-to-rail goods movement lowers production costs in both the maritime and rail industries. Goods movement projects tend not to impact consumers and commuters.

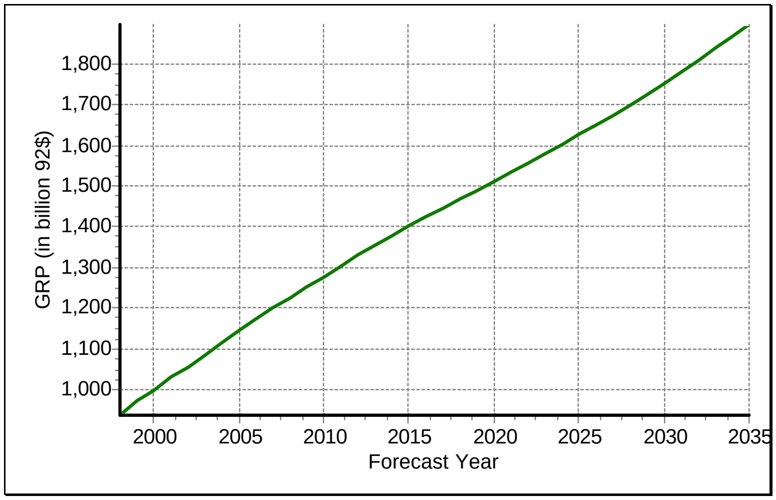
Commuters are impacted by projects that target local or region transportation. For instance, urban highway or local road projects reduce commuting time. In the REMI model, these types of projects are treated as amenity gains (i.e. something that increases the desirability of a particular area). Commuters are also benefited by local transit projects that reduce travel times.

4.2 Interpreting Output Produced By REMI

REMI produces forecasts for a variety of economic measures, including demand, output, GRP, personal income, and employment. The output can show the level of economic activity for the control forecast or the policy forecasts. It can also compare the two forecasts by calculating the difference or the percent change. The detailed results can be displayed graphically or in tabular form.

For example, Exhibit 4 shows the California GRP for the control forecast.

Exhibit 4
California Gross Regional Product



Source: REMI Policy Insight Model

The TASC proposed that the candidate measure for economic well-being be used to track changes in the transportation share of economic activity. REMI includes nine industrial sectors directly related to transportation:

- Motor Vehicle Manufacturing
- Rest of Transportation Manufacturing
- Petroleum Products
- Railroads
- Trucking
- Local/Interurban Transportation
- Air Transportation
- Other Transportation
- Automobile Repair Services.

However, these industrial classifications may not capture all of the regional economic activity related to transportation. For example, automobile insurance cannot be separated from general insurance. In addition, in-house transportation is not included in these industries. For instance, a logging company that hauls its own lumber, rather than hiring a trucking company, generates transportation-related activity and is not included in either the REMI trucking or other transportation categories.

These industries may also include a small portion of non-transportation related activity. For example, petroleum products can be used for heating rather than transportation.

The problem of in-house transportation may be solved by using the Transportation Satellite Accounts developed jointly by the Bureau of Transportation Statistics (BTS) and the Business Economic Area (BEA). These tables identify the portion of economic activity in non-transportation industries that is associated with transportation. The Appendix lists industries for which production costs are affected by highway investments.

5. CASE STUDIES

To test the applicability of REMI for measuring economic well-being, the REMI model was run for two hypothetical case studies. The case studies involved different levels of investment to examine the sensitivity of the measures to investments:

- The first case study shows the impact of the construction of a single intermodal facility on the California economy.

- The second case study measures the impact of a bundle of investments.

For both case studies, the policy (build) case was compared to the (no-build) control case using a 53-sector model that treats California as a single region. Impacts were forecasted from 2002 to 2035.

The transportation investments were modeled by measuring changes in six critical areas:

- Construction and construction financing
- Public transportation
- Environmental impacts
- Tourism
- Cost savings for businesses
- Cost savings (including safety improvements) for consumers and commuters.

The methodology used to model these changes is described further in Section 4.1.

The number and type of inputs to the REMI model depended on the specific transportation projects contained in each case study and are described in the sections that follow. The list of inputs for both hypothetical case studies are summarized in Tables 2 and 3. Appropriate inputs were developed using data from actual case studies provided by REMI.

5.1 Case Study One: Construction Of Intermodal Facility

The first case study shows the economic impact of a $55 million (in 1992 dollars) project to construct an intermodal facility that serves railroads and ships. The sum of the increase in GRP that results during the period from 2002 to 2035 is $1.2 billion. The economic impact of this project is felt primarily in the construction industry in the first few years and in the shipping and rail industries in later years. This cycle is typical of a project that facilitates goods movement.

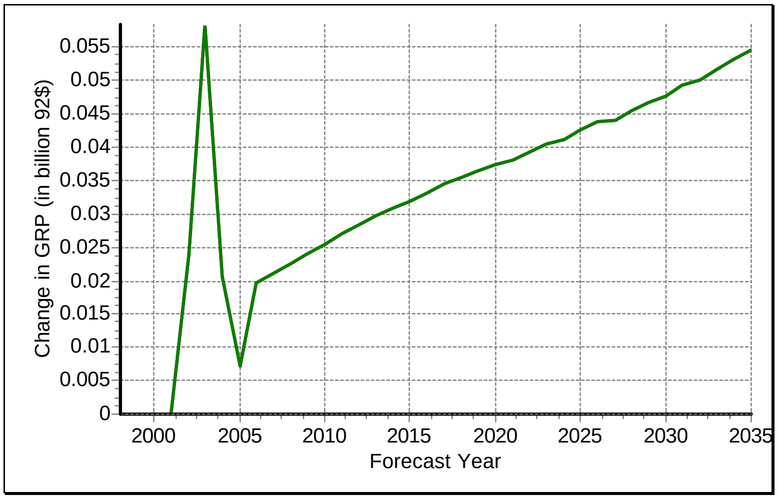
Table 2 shows the policy variables that were inputted to measure the impact of the project. Values for each of these variables were entered for 2002 to 2035. The first two variables are construction and maintenance costs associated with the facility. The remaining variables capture government and business impacts. Section 4.1 discusses these variables in more detail.

Table 2
Policy Variables Inputted for Intermodal Facility

Variable	Detail	Unit
Construction Sales (amount)	New Local Transit Facilities	1992 US $ (M)
Construction Sales (amount)	Maintenance and Repair Construction	1992 US $ (M)
Other Transportation Sales (amount)	Miscellaneous Transportation Services	1992 US $ (M)
State and Local Government Spending (amount)	Water and Air Facilities	1992 US $ (M)
Production Cost (share)	Railroad	Percent
Production Cost (share)	Other Transportation	Percent
Production Cost (amount)	Other Transportation	1992 US $ (M)

Exhibit 5 shows the impact of the project on *statewide GRP*. The Exhibit shows the typical boom-and-bust cycle of a transportation investment. The initial spike is due to the construction of the facility, which is followed by a drop due to the completion of the project. In later years, the project increases statewide GRP as California business become more productive and/or non-California business become more likely to relocate to California (REMI is unable to separate these two effects).

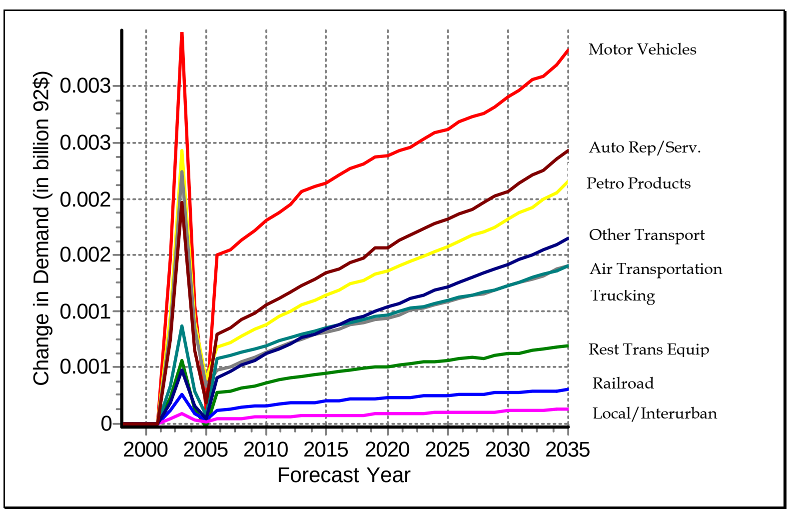
Exhibit 5
Change in Statewide GRP Due to Construction of Intermodal Facility



Source: REMI Policy Insight Model

As Exhibit 6 shows, the impacts on *transportation-related demand* are similar to those on GRP. Demand spikes during construction are followed by a slight bust and then a longer-term growth period. The demand for all transportation (including non-rail or highway) modes increases due to construction and migration into California.

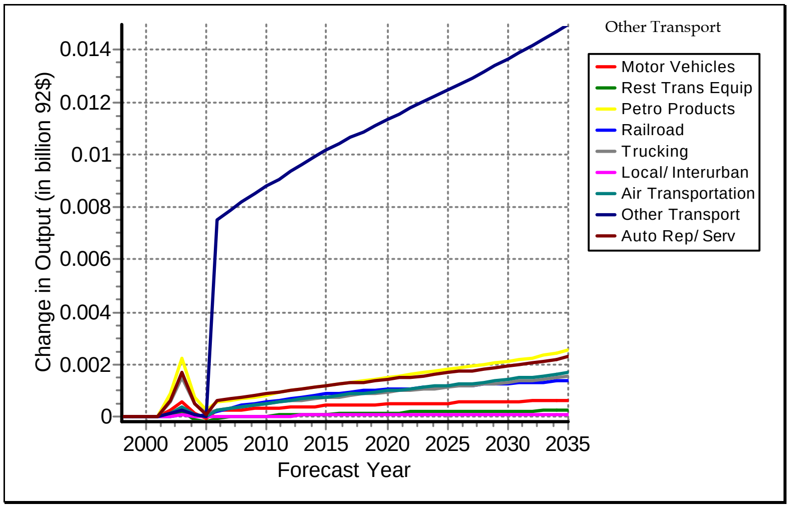
Exhibit 6
Change in Transportation-Related Demand Due to Construction of Intermodal Facility



Source: REMI Policy Insight Model

Exhibit 7 shows the impact of the project on transportation-related output. Although the same general boom-and-bust pattern occurs, the impacts are not felt equally by all industries. The increase in output is felt primarily in the Other Transportation Services industry (the line at the top of the graph), which includes maritime shipping.

Exhibit 7
Change in Transportation-Related Output Due to Construction of Intermodal Facility



Source: REMI Policy Insight Model

Similar graphs can be produced to show the effect of constructing the intermodal facility on regional employment and personal income.

5.2 Case Study Two: Bundle Of Transportation Projects

The second case study analyzed a bundle of projects, which is roughly the size and composition of the 1998 State Transportation Improvement Program (STIP) Augmentation cycle. Total construction cost for the bundle of projects is $675 million (in 92$) statewide over a period of six years beginning in 2002.

The investment program includes several different transportation modes, which have varying impacts on the economy:

- Intercity Highway (25% of investment program) – primarily benefits trucking industry
- Urban Highway (37.5%) and Local Roads (30%) – impacts off-the-clock travel (commuting) and the trucking industry
- Bus Transit (2.5%) – impacts off-the-clock travel (commuting)

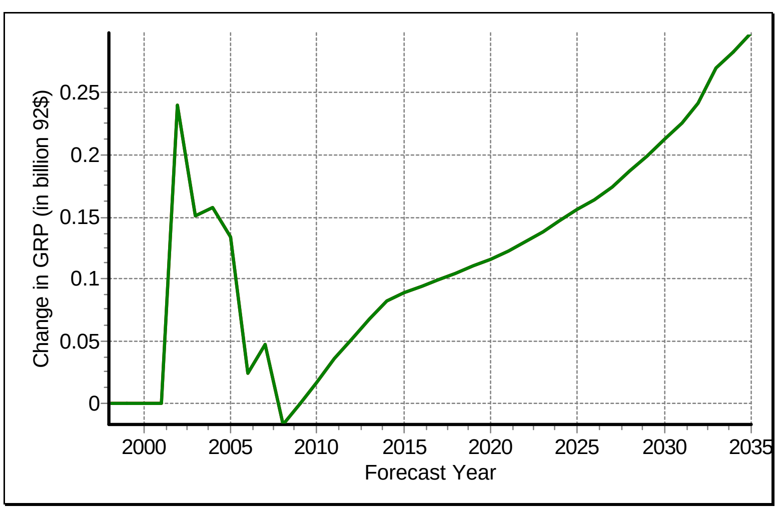
Intercity Rail (5%) – primarily benefits rail industry.

Since highway projects also benefit industrial sectors with in-house trucking, the BTS/BEA Transportation Satellite Accounts were used to allocate the reduced production costs. This adjustment was not made in the previous case study, since few companies or industries have in-house shipping or railroads. The Appendix lists the industries with reduced production costs due to highway projects.

Table 3, beginning on the next page, shows the other policy variables that were changed to measure the impact of the investment bundle. These variables were used to run the model, but high-level summary information such as that presented in the exhibits that follow should be presented to policy makers. The table separates the variables by the modes of the individual projects, but the effects were not counted more than once in the REMI simulation. Values were inputted for each of the listed variables from 2002 to 2035. Section 4.1 discusses these variables in more detail.

Exhibit 8 shows the change in statewide GRP that results from this bundle of investments. The sum of the increase in GRP that results during the period from 2002 to 2035 is $4.6 billion (in 1992 dollars). As in the first case study, an initial spike in GRP due to construction expenditures is followed by a slight decline in 2008 as the construction ends. The decline has a stair-stepped quality. This is because the individual transportation investments require different lengths of construction. In later years, GRP increases as California productivity improves and non-California businesses chose to relocate to California.

Exhibit 8
Change in Statewide GRP Due to Bundle of Transportation Investments



Source: REMI Policy Insight Model

Table 3
Policy Variables Inputted for Bundle of Transportation Investments

Investment Type/Variable	Detail	Unit
Intercity Highway		
Construction Sales (amount)	New Roads	1992 US $ (M)
State and Local Government Spending (amount)	Highways	1992 US $ (M)
Production Cost (amount)	Trucking	1992 US $ (M)
Non-Pecuniary (Amenity) Aspects (amount)	Labor Force and Dependents	1992 US $ (M)
Consumer Spending by Residents (amount)	Vehicles and Parts	1992 US $ (M)
Consumer Spending by Residents (amount)	Gasoline and Oil	1992 US $ (M)
Consumer Spending by Residents (amount)	Medical Care	1992 US $ (M)
Consumption Reallocation by Residents (amount)	All Consumption Sectors	1992 US $ (M)
Government Spending (amount)	State and Local	1992 US $ (M)
Production Cost (amount)	*Other Industries (allocated by BTS/BEA data)**	*1992 US $ (M)*
Urban Highway		
Construction Sales (amount)	New Roads	1992 US $ (M)
State and Local Government Spending (amount)	Highways	1992 US $ (M)
Production Cost (amount)	Trucking	1992 US $ (M)
Non-Pecuniary (Amenity) Aspects (amount)	Labor Force and Dependents	1992 US $ (M)
Consumer Spending by Residents (amount)	Vehicles and Parts	1992 US $ (M)
Consumer Spending by Residents (amount)	Gasoline and Oil	1992 US $ (M)
Consumer Spending by Residents (amount)	Medical Care	1992 US $ (M)
Consumption Reallocation by Residents (amount)	All Consumption Sectors	1992 US $ (M)
Visitor Days	Hotel or Motel	Thousands
Visitor Days	Rent Apartment or Home	Thousands
Visitor Days	Stay with Friend or Relative	Thousands
Visitor Days	Camper	Thousands
Visitor Days	Daytripper	Thousands
Government Spending (amount)	State and Local	1992 US $ (M)
State and Local Government Spending (amount)	Highways	1992 US $ (M)
Production Cost (amount)	*Other Industries (allocated by BTS/BEA data)**	*1992 US $ (M)*
Local Roads		
Construction Sales (amount)	New Roads	1992 US $ (M)
State and Local Government Spending (amount)	Highways	1992 US $ (M)
Production Cost (amount)	Trucking	1992 US $ (M)
Non-Pecuniary (Amenity) Aspects (amount)	Labor Force and Dependents	1992 US $ (M)
Consumer Spending by Residents (amount)	Vehicles and Parts	1992 US $ (M)
Consumer Spending by Residents (amount)	Gasoline and Oil	1992 US $ (M)
Consumer Spending by Residents (amount)	Medical Care	1992 US $ (M)
Consumption Reallocation by Residents (amount)	All Consumption Sectors	1992 US $ (M)
Visitor Days	Hotel or Motel	Thousands
Visitor Days	Rent Apartment or Home	Thousands
Visitor Days	Stay with Friend or Relative	Thousands
Visitor Days	Camper	Thousands
Visitor Days	Daytripper	Thousands
Government Spending (amount)	State and Local	1992 US $ (M)
State and Local Government Spending (amount)	Highways	1992 US $ (M)
Production Cost (amount)	*Other Industries (allocated by BTS/BEA data)**	*1992 US $ (M)*

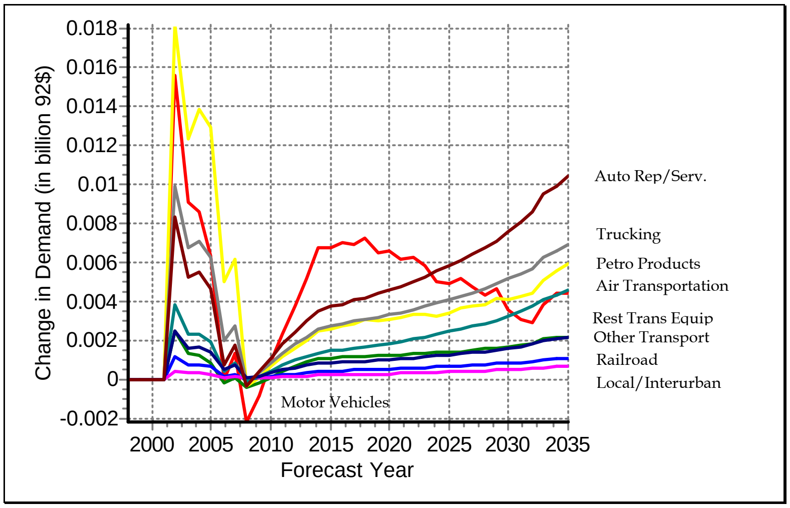
* *See the Appendix for list of industries.*

Table 3 (continued)
Policy Variables Inputted for Bundle of Transportation Investments

Investment Type/Variable	Detail	Unit
Bus Transit		
Construction Sales (amount)	New Local Transit Facilities	1992 US $ (M)
Demand (amount)	Motor Vehicles	1992 US $ (M)
State and Local Government Spending (amount)	Other Commerce and Transportation	1992 US $ (M)
Non-Pecuniary (Amenity) Aspects (amount)	Labor Force and Dependents	1992 US $ (M)
Consumer Spending by Residents (amount)	Vehicles and Parts	1992 US $ (M)
Consumer Spending by Residents (amount)	Gasoline and Oil	1992 US $ (M)
Consumer Spending by Residents (amount)	Medical Care	1992 US $ (M)
Consumption Reallocation by Residents (amount)	All Consumption Sectors	1992 US $ (M)
Government Spending (amount)	State and Local	1992 US $ (M)
Consumer Spending by Residents (amount)	Vehicles and Parts	1992 US $ (M)
Consumer Spending by Residents (amount)	Gasoline and Oil	1992 US $ (M)
Consumer Spending by Residents (amount)	Medical Care	1992 US $ (M)
Consumption Reallocation by Residents (amount)	All Consumption Sectors	1992 US $ (M)
Intercity Rail		
Construction Sales (amount)	New Local Transit Facilities	1992 US $ (M)
Construction Sales (amount)	Maintenance and Repair Construction	1992 US $ (M)
Other Transportation Sales (amount)	Miscellaneous Transportation Services	1992 US $ (M)
Production Cost (share)	Railroad	Percent
Production Cost (amount)	Railroad	1992 US $ (M)

Exhibit 9 shows how the bundle of transportation improvements impact demand in transportation-related industries. Across all industrial sectors, demand shows the typical boom-and-bust cycle. The largest increases occur in the petroleum and automobile manufacturing sectors. After the recovery, the demand for motor vehicles spikes for awhile, until highway congestion begins to reduce the demand. The increases in railroad and local/inter-urban industries is less than that for other transportation-related industries, because the bus transit and inter-city rail projects comprised a small portion of the overall investment package.

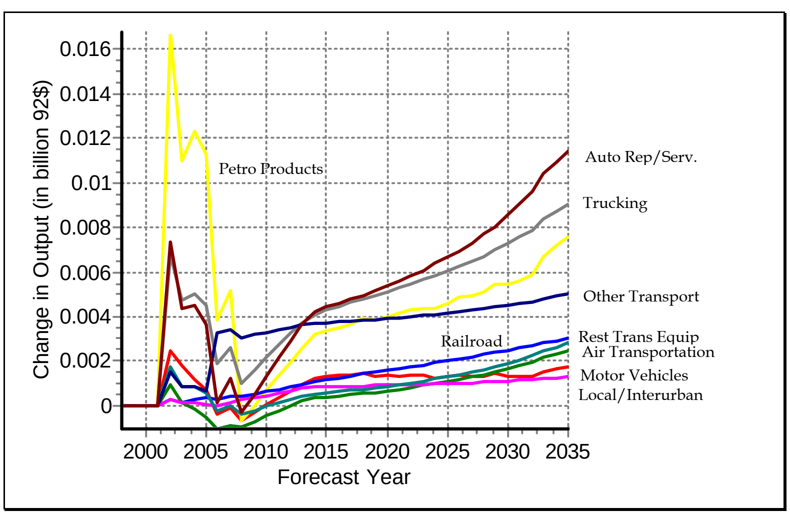
Exhibit 9
Change in Transportation-Related Demand Due to Bundle of Transportation Investments



Source: REMI Policy Insight Model

Exhibit 10 shows the impacts of the transportation investment bundle on output for each of the transportation-related industries. The impacts on petroleum output are similar to the impacts on petroleum demand, since petroleum in California is largely produced. Automobile repair services and trucking also benefit from the investment package. This effect is primarily due to the highway focus of the investments.

Exhibit 10
Change in Transportation-Related Output Due to Bundle of Transportation Investments



Source: REMI Policy Insight Model

Similar graphs can be produced to show the effect of the bundle of transportation investments on regional employment and personal income.

6. FINDINGS AND CONCLUSIONS

Economic well-being *can be measured* for transportation system performance at the state, regional, and county level. Three potential indicators for measuring economic well-being, as defined by the TASC, have been identified:

- Gross Regional Product (GRP)
- Demand
- Output.

The TASC intended for the candidate measure to be used to track changes in transportation-related economic activity and to show whether the transportation share of economic production is rising, declining, or maintaining current levels.

Demand is closest in definition to the indicator defined by the TASC in the first phase of the Performance Measurement initiative. Demand measures *the value of goods and services purchased within a region* (including imports) and can be calculated for several *transportation-related* industrial sectors:

- Motor Vehicle Manufacturing
- Rest of Transportation Manufacturing
- Petroleum Products
- Railroads
- Trucking
- Local/Interurban Transportation
- Air Transportation
- Other Transportation
- Automobile Repair Services.

These industrial classifications may not capture all of the regional purchases related to transportation (e.g., automobile insurance and in-house transportation), but most are covered. The problem of in-house transportation may be solved by using the Transportation Satellite Accounts developed jointly by the Bureau of Transportation Statistics (BTS) and the BEA.

The demand indicator can be supplemented by output and GRP, which measure production and the creation of economic value.

Other indicators, such as personal income and employment, measure aspects of economic well-being that directly concern California residents. While these indicators do not match the definition of economic well-being provided by the TASC, they may be useful to include in the performance measurement framework.

The REMI regional model can measure transportation-related demand and forecast changes in demand due to transportation improvement projects. Since REMI can also generate the other two indicators, all three should be presented to policy makers, who can then decide which to use. REMI can also measure other economic indicators, such as personal income and employment. However, this technical memorandum has not focused on these measures, since they do not correspond to economic well-being as defined by the TASC.

The two case studies presented in this memo demonstrate that all three potential indicators (demand, output, GRP) are sensitive to the level of transportation investment. Analyzing individual projects probably makes more sense for local governments than for the State or regions. State and regions should focus instead on groups of transportation investments.

APPENDIX

Industries with Production Costs Affected by Highway Investments According to BTS/BEA Transportation Satellite Accounts

1. Agriculture, Forestry, and Fishery Services
2. Air Transportation
3. Amusement and Recreation
4. Apparel
5. Auto Repair and Service
6. Banking
7. Chemicals
8. Communication
9. Construction
10. Credit and Finance
11. Eating and Drinking
12. Education
13. Electrical Equipment
14. Fabricated Metals
15. Food
16. Furniture
17. Hotels
18. Instruments
19. Insurance
20. Leather
21. Local and Interurban Transportation
22. Lumber
23. Machinery and Computers
24. Medical
25. Mining
26. Miscellaneous Business Services
27. Miscellaneous Manufacturing
28. Miscellaneous Professional Services
29. Motion Pictures
30. Motor Vehicles
31. Non-Profit Organizations
32. Other Transportation
33. Paper
34. Personal Services and Repair
35. Petroleum Products
36. Primary Metals
37. Printing
38. Private Household
39. Public Utilities
40. Railroad
41. Real Estate
42. Rest of Retail
43. Rest of Transportation Equipment
44. Rubber
45. Stone, Clay, and Glass
46. Textiles
47. Tobacco
48. Wholesale

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Travel Demand Model Review
Technical Memorandum

Booz·Allen & Hamilton Inc.
June 30, 1999

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This Technical Memorandum is a review of current statewide travel demand modeling efforts and addresses the level of consistency (or lack thereof) among the different methods employed by different Metropolitan Planning Organizations (MPOs), Regional Planning Agencies (RPAs), and other local and state planning agencies. The objective is to develop an inventory of transportation demand models and modeling assumptions used by regional agencies throughout the State. This effort is part of the California Transportation System Performance Measurement initiative that started in 1998, led by the Business, Transportation, and Housing Agency.

With this objective in mind, Booz·Allen designed a survey titled "Statewide Travel Demand Model Survey" (the Survey). The Survey addresses demand modeling platforms for highway, street, and transit networks, and consisted of the following four sections:

- General Model Methodology
- Supply Information
- Demand Information
- Economic/Demographic/Forecast Assumptions.

The Survey was administered to 25 travel demand forecasting & modeling units representing various state and regional agencies throughout California. Nineteen completed surveys were returned and analyzed. A general synopsis of the Survey's results, summarized by each major section, follows.

- General Model Methodology

  - There is little conformity with regard to the general modeling methodologies employed for travel demand modeling, and the parameters surrounding these methodologies

  - More similarities exist between agencies representing similar types of regions (e.g., major metropolitan areas)

  - MINUTP is reported as the most commonly used modeling software across all respondents. However, major metropolitan areas use mainly TRANPLAN

  - Model base years varied significantly across the different agencies surveyed, as did base year model updates, implying that comparisons across different model outputs will be difficult

- Agencies representing large metropolitan areas tend to forecast travel demand for a wider range of times of day and forecasting periods (e.g., base year, weekday) than agencies representing small urban and rural areas

- Supply Information

  - Freeways," "expressways," and "other major streets" are the transportation network classifications most common in travel demand models

  - Small collector streets and transit modes (e.g., bus, rail) are incorporated to a lesser degree especially by small urban and rural models

  - Major metropolitan area models incorporate a wider range of transportation network and mode classifications than do small urban and rural area models

- Demand Information

  - Most models produce both vehicle trip and person trip forecasts

  - Cross-classification and multi-linear regression are the methods most commonly used in determining the total number of trips originating and ending in a zone

  - The gravity model is the most widely used model type

  - Home-based work, home-based shopping, and home-based other are the most common trip categories reported

  - Truck/commercial vehicle modes are rarely incorporated directly into travel demand models, although several upgraded models will have this capability in the future

  - Transit demand is modeled mainly by large metropolitan areas and not by small urban and rural areas. Across metropolitan areas, the level of detail for transit modeling varies from route-specific to generalized approaches

- Economic/Demographic/Forecast Assumptions

  – Major metropolitan areas are more likely than smaller urban and rural areas to incorporate multiple types of economic, demographic, and other variables

  – Economic and demographic data sources range from the State's Department of Finance, Regional Planning Agencies, General Plans and the 1990 Census

  – Larger agencies referenced data sources such as major universities and their respective Regional Planning Agencies.

In conclusion, the Survey results suggest four main challenges to the establishment of a more consistent forecasting methodology statewide:

– Reducing discrepancies across different agencies with regard to their election of model horizon and forecast years, and establishing standard horizon and forecast years. Otherwise, year to year comparisons across regions will be difficult

– Ensuring that agency models incorporate similar economic and demographic variables, and that the sources and assumptions used for generating the variables are compatible

– Ensuring that highway and transit networks are accounted for and incorporated into models across the state regardless of size and complexity of the region or area for which travel demand is being forecasted

– Incorporating freight/commercial vehicle modes directly into travel demand models statewide. Most agencies either ignore this mode altogether or base forecasts on assumptions developed outside their models. Unfortunately, this is typical nationwide.

Performance measures can help steer regions and agencies towards more consistent travel demand methodologies, however achieving state-wide standardization is unrealistic at this time.

1. INTRODUCTION

Booz·Allen & Hamilton Inc. is presently working with the California Department of Transportation (Caltrans) for Phase II of the System Performance Measure initiative. This Technical Memorandum represents the end product of Task 5 in this project. It addresses current, statewide travel demand modeling efforts and levels of consistency among the different methods employed by different Metropolitan Planning Organizations (MPOs), Regional Transportation Planning Agencies (RTPAs), and other local and state planning agencies.

The goal of this task was to assist in the development of a framework for attaining increased consistency among modeling methods and assumptions, and, hence, facilitate transportation planning and performance measurement efforts statewide. With this objective in mind, Booz·Allen designed a "Statewide Travel Demand Model Survey" (the Survey) to be administered throughout the State. The Survey addresses demand model platforms for highway, street, and transit networks.

2. SURVEY STRUCTURE

The Survey consisted of 17 questions that required approximately 15 minutes to complete. Question types ranged from simple "fill in the blank" to more descriptive and open ended questions. A copy of the survey instrument has been included in Appendix A of this document for easy reference.

The Survey was divided into four parts:

- General Model Methodology – which poses some general questions about the travel demand model(s) used by the respondents
- Supply Information – which addresses the different methodologies employed to describe the supply or level of services that are available to travelers within the networks being modeled
- Demand Information – which probes into the methods used to segment different trip types and travel markets
- Economic/Demographic/Forecast Assumptions – which address the different variables used in developing model forecasts.

3. SURVEY RESPONDENTS

Twenty five survey packages where sent to the travel demand forecasting and modeling units of State and regional agencies throughout California. All packages included a cover letter explaining the importance of each agency's collaboration. Potential respondents were informed of the California transportation system performance measurement initiative and its goals. All individuals were asked to complete the Survey and return it to the Booz·Allen & Hamilton offices, by June 15, 1999. Of the 25 agencies contacted, 19 returned completed surveys, or 73 percent:

- Butte County Association of Governments
- California Air Resources Board (CARB)
- California Energy Commission
- City of Modesto
- Council of Fresno County Governments
- Kern County Council of Governments
- Merced County Council of Governments
- Metropolitan Transportation Commission (MTC)
- Orange County Transportation Authority (OCTA)
- Sacramento Area Council of Governments (SACOG)
- San Joaquin Council of Governments
- San Diego Association of Governments (SANDAG)
- Santa Barbara County Association of Governments (SBCAG)
- Santa Clara County (Center for Urban Analysis)
- Southern California Association of Governments (SCAG)
- Tahoe Regional Planning Agency
- Transportation Agency for Monterey County
- Tulare County Association of Governments
- Ventura County Transportation Commission.

Respondents generally adhered to the Survey's format; no surveys were dismissed. In the event that format was not adhered to, affected responses were counted as a "no response" or "other response" category and as such were not included in the analysis. A survey key consisting of all responses is included in Appendix B for reference.

The proceeding sections contain survey result analyses.

4. TRAVEL DEMAND MODEL SURVEY

The following sections follow the Survey's exact structure. The analysis is grouped into four parts:

- General Model Information;
- Supply Information;
- Demand Information; and
- Economic/Demographic/Forecast Assumptions.

4.1 General Model Information

The Survey's results reveal that, across the 19 agencies represented, there is a low level of conformity with regard to the general methodologies employed for travel demand modeling, and the parameters surrounding these methodologies. One agency forecasts annual vehicles and vehicle miles traveled to model energy demand (California Energy Commission) Two agencies – The California Energy Commission and the California Air Resources Board -- have no need for and do not maintain travel demand models. Sixteen of the 19 agencies employ travel demand models for transportation planning purposes. For this reason, the following analysis considers only these 16 agencies where appropriate.

Of the 16 travel demand models represented throughout most of this section, all have base years between 1990 and 1998. The largest percentage (44 percent) uses 1990 as their base year. All respondents indicated that their model's official base years had been updated within the last five years. Most respondents indicated that their models' use a horizon year of 2020. However, the intervening forecast years leading to the horizon year, or beyond, vary significantly.

Respondents differ considerably with regard to the time periods (e.g., AM, PM) and forecasting periods (e.g., base year, weekday) for which they model travel demand.

A more detailed analysis of each question is provided next:

Q.I.1 What type of modeling software system(s) do you use?

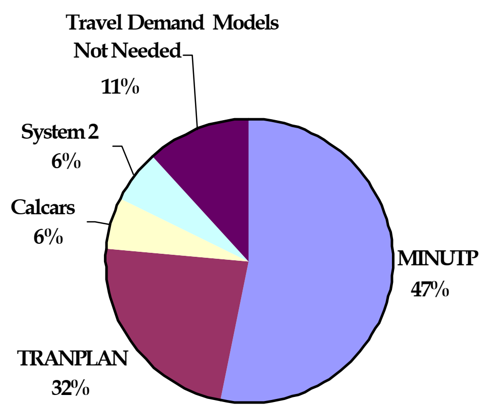
Nineteen individuals responded to this question. Forty-seven percent of the Survey's respondents indicated that their agencies currently used MINUTP modeling software for forecasting travel demand. Of these agencies, one-third indicated that they will be upgrading to a later version in the near future.

The MINUTP modeling software provides a representation of the region or area's highway and transit systems, which includes both transportation facilities, bus routes, and policies such as HOV restrictions, access metering, transit service levels, and fares. MINUTP provides transportation planners with the capability of developing, maintaining, and altering highway and transit networks in order to represent the full range of options for new construction projects and alternative operating policies. MINUTP follows the widely accepted four-step demand forecasting process, which includes trip generation, trip distribution, mode choice, and trip assignment. For more specifics on MINUTP, refer to its website at: www.boulevard.com/comsis/minutp.

The second most popular software package is TRANPLAN –used by 32 percent of respondents. TRANPLAN seems to be used only by agencies from major metropolitan areas. Smaller urban and rural agencies, and statewide planning agencies, use MINUTP or some other modeling software. One agency uses System 2 software. The California Energy Commission (CEC) uses CALCARS software for forecasting energy demand and not for transportation planning purposes. The respondent from SCAG indicated that the agency used both EMME/2 and TRANSCAD modeling software packages in addition to TRANPLAN. Two respondents indicated that their agencies have no need for travel demand models.

The survey results for this question are summarized in Exhibit 1.

Exhibit 1
Travel Demand Modeling Software Used



Q.I.2 What is the official base year(s) for your model?

Seventeen individuals responded to this question. All respondents indicated that their travel demand model's official base year lies between 1990 and 1999. Forty-one percent use 1990. There is a heavier weight of responses leaning toward the first half of the

1990s – 70percent of respondents' models have base years between 1990 and 1995. The survey results for this question are summarized in Table 1.

Table 1
Base Years for Travel Demand Forecasting

Base Year	Number of Respondents	Percentage (%)
1990	7	41
1994	3	17
1995	2	12
1996	1	6
1997	2	12
1998	1	6
1999	1	6
TOTAL	**17**	**100**

Q.I.3 When was the last time your base year model(s) was updated?

Respondents were instructed to indicate both month and year of their last update. However, since very few indicated the month all responses were analyzed by year only. All indicated that their models' base years have been updated within the last five years, and over half had been through updates within the last two years, as shown below.

Table 2
Year of Last Base Year Update

Last Model Update	Number of Respondents	Percentage (%)
1994	2	12
1995	4	23
1996	2	12
1997	2	12
1998	3	18
1999	4	23
TOTAL	**17**	**100**

Q.I.4 How often do you update your model's official base year?

Seventy percent of respondents indicated that their model's base year is estimated at least once every five years, as shown in Table 3. One respondent's agency performs an update annually, and three (20 percent) perform an update every three to four years. Only 13 percent of respondents indicated that their agencies' perform base year updates every ten years. Twenty percent perform them as needed. One respondent indicated that "as needed" implies "when there is damage either to the underlying data base or to the model's structure.

Table 3
Frequency of Base Year Update

Frequency of Base Year Update	Number of Respondents	Percentage (%)
1 – 2 years	1	6
3 – 4 years	4	23
5 years	7	41
10 years	2	12
As needed	3	18
TOTAL	**17**	**100**

Q.I.5 What is your official horizon year?

Most respondents (76 percent) indicated that their models forecast demand at least through 2020. Santa Clara County's Center for Urban Analysis projects demand through the year 2025, and the Tulare County Association of Governments projects demand through the year 2030. The remaining four respondents indicated that their models have horizon years other than 2020.

Of the 13 respondents whose models project demand through 2020, five indicated that demand is also projected for every five years leading up to 2020 (e.g., 2005, 2010, 2015). Two of these respondents indicated that their models used ten-year increments leading up to 2020, and six did not specify their corresponding annual increments. In general, most models appear to forecast travel demand in five-year increments leading up to the year 2020.

Q.I.6 What time periods do you model?

Of the 18 individuals who responded to this question, 17 were taken into consideration for this analysis: those who indicated that their respective agencies had travel demand modeling capabilities. Comments from the 18th respondent were not taken into consideration in order to preserve the quality of the Survey's information – this respondent indicated that demand figures were taken directly from COG/MPO demand models.

In general, the 17 respondents indicated that their agencies forecast travel demand for base years, forecast (horizon) years, and weekdays. All agencies that project base year demand also project demand for their respective forecast years. Weekend demand is not projected by any of the 17 agencies represented.

Table 4 presents the brunt of the information generated from this question. Each cell represents the percentage of the agencies that forecast travel demand for a specific time period (e.g., AM peak, PM peak) and forecasting period (e.g. base year, forecast year, weekday). For example, 24 percent of the agencies forecast base year demand based on a one-hour AM peak. Twenty-nine percent forecast mid-day weekday demand.

Table 4
Time Periods Modeled (Percent of Respondents)

Time Period	Base Year	Forecast Years	Weekday	Weekend
AM Peak 1 Hr	.24	.24	.24	-
PM Peak 1 Hr	.29	.29	.29	-
AM Peak Other	.53	.53	.53	-
PM Peak Other	.47	.47	.47	-
Mid-day	.29	.29	.29	-
Daily	.76	.76	.76	-
Other	.29	.29	.24	-

The responses indicate that the majority of agencies (76 percent) forecast daily demand for each forecasting period. Fifty-three percent of the agencies project PM Peak demand for a length of time other than one hour; 53 percent project AM Peak demand for a length of time other than one hour. Table 5 shows the length of the period for which agencies project demand for the AM peak and PM peak.

Table 5
Non-Hourly Peak Models

	Respondents Using:		
Peak Period Length	AM Peak	PM Peak	Midday
2 hours	1	1	1
3 hours	6	4	-
4 hours	-	2	-
6 hours	-	-	2

Six respondents indicated that their model's AM and PM peak periods last three hours as opposed to one hour. Other models peak period durations were two hours (AM) and four hours (PM). Midday durations were either two hours or six hours. Two respondents indicated that their respective agencies also project daily off-peak demand for the AM and PM periods. The respondent representing the Tahoe Regional Planning Agency indicated that their model projects daily demand for base year and forecast years. In addition, the respondent specified that weekday demand was forecast only for Fridays in August. The respondent representing SCAG indicated that the agency also forecasts demand for eleven-hour period during the evenings.

4.2 Supply Information

In general, most agencies' travel demand models account for major network classifications such as freeways, expressways and major streets (i.e., arterials). Major metropolitan area models incorporate a wider range of transportation network and mode classifications and than small urban and rural area models. Questions concerning supply are presented next.

Q.II.1 At what level of detail does your model network represent streets, roads, and transit?

The number of respondents for this question varied between nine and 16, depending on the particular network classification. In general, models used in major metropolitan areas incorporate more network classifications than those used in small urban and rural areas.

Table 6 summarizes the results listed in percentage of total respondents whose models account for the network classifications listed (e.g., freeways, major collectors). The number of respondents is listed, per classification, in the table's last column. This information was included to highlight that there was a variance in the number of respondents per network classification. The classifications "Most Included" and "Some included" were not defined in the survey. Instead, the definitions were left to the interpretation of the respondents. The objective was to develop a general understanding for the complexity of the models being used.

Percentages were calculated based on the number of respondents per classification. Percentages were not calculated based on the number of total survey respondents. An example of how to read each entry follows: 55 percent of respondents (6 out of 11) indicated that their travel demand models incorporate all commuter/urban rail lines within their region or area. The survey did not reveal whether this was because commuter/urban rail was not offered in the area being modeled or for some other reason. For example the Tahoe Regional Planning Agency's model does not incorporate freeways, expressways, and HOV lanes because these facilities are not present in its existing network.

Table 6
Network Classifications (Percent of Respondents)

Network Classification	All Included in Model	Most Included	Some Included	None Included*	No. of Respondents**
Freeways & Expressways	.87	-	-	.13	**16**
HOV lanes as separate links	.78	-	-	.22	**9**
Other Principal Arterials	.86	.07	-	.07	**15**
Major Collectors	.63	.31		.06	**16**
Minor Collectors	.07	.53	.33	.07	**15**
Other Streets/Roads	-	-	.64	.36	**14**
Commuter/Urban Rail	.55	.09	-	.36	**11**
Other Rail Links	.33	-	-	.66	**9**
Bus Routes	.33	.17	-	.50	**12**

* *"None included" means that the model does not incorporate the specific facility or mode regardless of whether or not the facility or mode is available in the region.* ** *Percentages are calculated based on the number of respondents for each respective network classification.*

The overwhelming majority of the respondents indicated that their models incorporate all freeways and expressways (87 percent), and other principal arterials (86 percent). Only 63 percent indicated that their models incorporate all major collectors. Slightly more than one half indicated that most minor collectors are included, and another 64 percent indicated that some other streets/roads are included.

In general, transit is not included in the models– this is true particularly of smaller urban and rural areas. Only half of the representative models incorporate all commuter/urban lines. Other rail links and bus routes are incorporated to a lesser extent, if at all – 66 percent of the models represented do not incorporate other rail links, and half do not incorporate bus routes. This is the case, almost exclusively, for small urban and rural areas where transit demand constitutes a relatively small percentage of total travel demand. All of the travel demand models from major metropolitan areas incorporate all or most of the transit classifications. The respondent from SCAG indicated that their 2020 plan includes a magnetic levitation train system linking the Southern California region's major airports.

Q.II.2 What modes are represented in your model (Check all that apply)?

Fifteen responses were evaluated for this question. All models account for automobiles: 53 percent did not distinguish between single occupancy vehicles (SOVs)and high occupancy vehicles (HOVs); 47 percent did distinguish between the two. Certain respondents indicated that their models represented general, SOVs, and HOVs, but for the purposes of this analysis, it is assumed that if the model takes occupancy into account, then it does not generalize. A similar assumption was made for rail transit classifications: if the model distinguishes between urban and commuter rail, then it does not combine. However, it should be noted that some respondents indicated that their models are sophisticated enough to account for all three classifications.

Although all models account for the automobile, fewer than half incorporate transit. Bus is the most highly incorporated transit mode – 40 percent of respondents' models represent bus in their networks. Models used by the Sacramento Area Council of Governments and the Santa Barbara County Association of Governments combine and account for all transit modes in one general category. SANDAG and SCAG models account for urban and commuter rail in a combined rail category. In general, larger metropolitan areas accounted for a wider range of modes. Conversely, most small urban and rural areas only model demand for general autos.

Table 7 summarizes the results for this question. Please note that the (SOV 3+) category has been eliminated from the analysis due to significant inconsistencies among the respondents.

Table 7
Multi-Modal Models

	Auto			Transit				
Mode	**General**	**SOV**	**HOV 2-Person**	**General**	**Bus**	**Combined Rail**	**Urban Rail**	**Commuter Rail**
Number of Respondents	8	7	7	2	6	2	4	3
Percent of Respondents	.53	.47	.47	.13	.40	.13	.27	.20

4.3 Demand Information

This section addresses how the models segment trip types and markets. The main demand characteristics include:

- Most models produce both vehicle trip and person trip forecasts
- Cross-classification and multi-linear regression are the methods used to estimate the total number of trips
- All respondents use the gravity model
- Home-based work (HBW), home-based shopping (HBS), and home-based other (HBO) are the trip types most commonly accounted for in the models surveyed

- Agencies don't normally model truck/commercial vehicle activity directly.

Q.III.1 What trip types does your modeling system produce?

About half of the Survey's respondents indicated that that their modeling systems produce both vehicle trips and person trips. The remaining responses modeled one or the other trip type, as shown in Table 8 below.

Three of the four agencies that model vehicle trips represent small urban or rural areas in the State, and the remaining agency is the statewide California Air Resources Board. It is preferable to model person trips because travel behavior is determined by human decisions, and in large metropolitan areas alternative modes can represent a sizeable travel market. However, in areas where transit carries few people (or at the statewide level where transit is a small share of all trip making activity), then modeling vehicle trips is appropriate. In either case, average vehicle occupancy estimates can be used to translate from one trip type to another. Average vehicle occupancy estimates come from regional analyses or surveys, but a number of agencies rely on the California *1991 Statewide Travel Survey* for these estimates.

Table 8
Trip Types

Trip Type	Number of Respondents	Percentage (%)
Person Trips	4	21
Vehicle Trips	4	21
Both Types	8	42
No response	3	16
TOTAL	**17**	**100**

Q.III.2 What type of trip generation analysis do you perform?

The trip generation model establishes a relationship between travel, land use, and socio-economic characteristics of an area. Two principle methods are used to determine the total number of trips originating and ending in a zone: cross-classification and multi-linear regression techniques.

- Cross-classification methods create "look-up" tables for trip rates by categorizing the population into socio-economic sub-groups (e.g., income, housing type, family size, or automobile ownership).

- Other techniques are variations of these two methods. For example, the San Diego Association of Governments (SANDAG) uses trip tables to "look up" household person trip generation rates by occupied dwelling unit structure type. Non-residential trip ends are estimated by applying trip rates to forecasts of non-residential land use by 80 land use categories.

Table 9 summarizes the results for this question.

Table 9
Trip Generation Methods

Trip Generation Method	Number of Respondents	Percentage (%)
Cross-classification	6	32
Regression	4	21
Trip Table	1	5
No response	8	42
TOTAL	**19**	**100**

Q.III.3 What type of trip distribution model do you use?

All respondents to this question (16) use a gravity model for their modeling efforts. The three remaining surveys did not respond to this question. The gravity model is a very common model used to allocate trips between origins and destinations.

Q.III.4 What trip purposes does your model account for?

All respondents indicated that their respective agencies' travel models account for HBW trips. Fifteen respondents indicated that HBS and HBO trips are also accounted for. This was true independent of whether the agency represented either a major metropolitan area or a smaller urban or rural area. One main difference between the major metropolitan agencies and the small urban or rural agencies is that the latter indicated that they also take non-home based shopping trips into account. In general, most agencies account for non-home based other trips.

Other trips which were commonly referenced included:

- Home-based school trips (stratified by grade level)
- Social and recreational trips
- Airport trips
- Visitor trips (in areas with large seasonal fluctuation like the Tahoe area.

Q.III.5 Can your model provide other market segmentation information after trips have been assigned?

Most respondents answered no to this question, as shown in Table 10 below. Three respondents who did not answer a "No" replied that market segmentation was possible, but it was either not a standard output, difficult to do, or had not been attempted at that agency.

The three affirmative responses are very informative. One agency segments the travel market by automobile ownership and income quartile. In addition, this agency segments Home-based High School and Home-based Social Recreation trips by automobile ownership. Another agency classifies trips by Drive Alone, HOV2, and HOV3+ as well as by toll and non-toll trips. This agency also stratifies trips by income (i.e., high, medium, low). Transit trips are stratified by mode of access to transit. The California Energy Commission models personal vehicle energy and stratifies travelers by income, number of workers per household, and household size.

Table 10
Market Segmentation

Market Segmentation	Number of Respondents	Percentage
No	11	58%
Yes	3	16%
Not standard output/Not Sure	3	16%
No response	2	10%
TOTAL	**19**	**100**

Q.III.6 How do you account for trucks/commercial vehicle travel activity? Describe.

The way in which the agencies surveyed account for truck/commercial vehicle activity depends heavily on whether the agency was in a major metropolitan area, a small urban or rural area, or a statewide planning agency. Approximately three quarters of the respondent agencies incorporate truck/commercial vehicle activity to some extent.

All of the agencies representing major metropolitan areas account for truck/commercial vehicle activity either directly in their models or indirectly from an outside source. Some indicated that they had separate freight forecasting models. One agency uses data from the California Air Resources Board air quality analyses, but confirmed that their new model will have truck/commercial vehicle traffic forecasting capabilities.

In general, most of the small urban and rural agencies represented in this survey either do not account for truck or commercial vehicle activity in their travel demand models, or they assume that it is a percentage of the automobile demand which *is* accounted for. One respondent indicated that his agency's travel demand model has the capability of incorporating truck/commercial vehicle activity but that relevant information concerning these modes is not used. For the most part, these responses are justified by the relatively small amount of truck/commercial vehicle traffic in most small urban and rural areas. In those cases were truck/commercial vehicle traffic is more significant, agencies indicated that traffic estimates are often calculated outside the model.

Statewide planning agencies, like the California Air Resources Board, have their own model for forecasting truck/commercial vehicle activity. These figures are used to model emissions and other elements affecting California's air quality.

4.4 Economic/Demographic/Forecasting Assumptions

Relatively few of the individuals surveyed provided responses for questions in this section. In general, the Survey's responses revealed that major metropolitan areas are more likely than smaller urban and rural areas to incorporate more types of economic, demographic, and other variables. Some models are more sophisticated than other, insofar as the level of detail of their assumptions. No agency accounted for gender differences with regard to transit accessibility.

Data sources vary. Smaller agencies rely more heavily on their representative cities' General Plans and on statewide data – especially when forecasting land use and economic trends. Larger agencies referenced data sources such as major universities and their respective Regional Planning Agencies (i.e., ABAG).

4.4.1 The following tables list commonly used variables in mode split, assignment, and trip generation modules. Please fill out the tables to the best of your knowledge.

<u>Mode Split/Network Assignment</u>

(Information Mode Split/Network Assignment tables is summarized below. A key containing the responses to this part of Question IV.1 is found in Appendix B.)

Fifty-three percent of the individuals surveyed provided responses to this section. Excluding the gender variable, 57 percent of respondents indicated that they use the various economic and demographic variables listed for mode split and network assignment purposes. The most widely used of these variables is travel time by auto (83 percent). The second most widely used variables is household income (73 percent). All respondents indicated that the gender variable is not accounted for in their respective models.

Of those respondents whose models consider these variables for modal split and network assignment methodologies, most (68 percent) represent agencies in major metropolitan areas. This implies that travel demand models for these areas tend to be more sophisticated, as they incorporate more of the characteristic of their respective regions. Table 11 summarizes the results for this question (Mode Split/Network Assignment) in terms of percentage of respondents who use the corresponding variables, total number of respondents per variable, and percentage of users representing agencies from major metropolitan areas.

Table 11
Economic & Demographic Variables Used for Mode Split & Network Assignment

Variable	Percent Respondents Using Variable	Number. of Respondents	Percent of Users from Major Metro Areas
Parking Cost	58	12	86%
Fuel Cost	36	11	75%
Veh. Operating Cost	50	10	80%
Toll Cost	44	9	75%
Bus Fares	60	10	67%
Travel Time by Auto	83	12	40%
Travel Time by Bus	50	10	80%
Auto Ownership	64	11	57%
Household Income	73	11	50%
Gender	0	8	-

Trip Generation

The following tables summarize responses to this question's trip generation section. Each table includes the variable type under consideration, a general summary of responses, a description of how the variables are used in the models, and the relevant data sources.

Variable Type: Personal
General:
Half of the interviewees responded to the section pertaining to *Personal* variables. Respondents represented a relatively even split between major metropolitan areas and smaller urban and rural areas. *Personal* variables included gender, age, personal income, occupation, and other. Only occupation and industry type factors were incorporated into agency modeling methodologies for estimating trip generation.
How are these variables used in the model?
The responses to this section were not very specific. The respondents indicated that different occupation categories were used when estimating trip generation across the region: retail, service, education, government, and other. Although none of the respondents elaborated on this issue, occupation and industry categories are tied to employment and can both be used in conjunction with land use and square footage estimates to approximate employee numbers in particular areas throughout the region

being modeled (e.g., CBD, industrials parks, etc.).
Data sources used in the model:
Sources cited included county, city, and 1990 census figures.

Variable Type: Household
General:
Seven individuals – out of a possible 17 – responded to this section. The variables that fell into the *Household* category included population, number in household, household type, family size, auto ownership, number of children, and household income. At least half of the respondents indicated that all of these variables except family size and number of children were taken into account in their model's estimation of trip generation. Only two out of six respondents indicated that family size was a variable in estimating trip generation, and no respondents claimed to use number of children. Other variables used included number of workers per household and household structure type. There was little indication that larger metropolitan areas took more of these factors into account than did smaller urban and rural areas.
How are these variables used in the model?
In general, the respondents were vague about their models' use of the various household variables. Many merely confirmed that they were factored into the trip generation process. The Santa Clara County Transportation Authority representative elaborated slightly, indicating that the agency used some household specific data to run attraction regressions.
Data sources used in the model:
In general, respondents indicated that most of the household data used for trip generation came from their respective regional planning agencies (e.g., ABAG, SCAG) or Census data.

Variable Type: Zonal
General:
Seven out of 17 individuals indicated whether or not their respective agencies' travel demand models incorporated zonal variables into their trip generation methodologies. The variables included in the zonal classification included land use, residential density, accessibility, retail employment, non-retail employment, total employment, CBD/non-CBD, dwelling units, retail/non-retail areas, and ITE trip generation figures. Of those who responded, more than half indicated that their models' trip generation calculations included factors for residential density, retail employment, non-retail employment, total employment, and dwelling units. Whether or not the respective agencies were in a major metropolitan area did not appear to factor into this outcome. More than half of the respondents indicated that their trip generation models did not factor in land use, accessibility, CBD/non-CBD, retail/non-retail, and ITE trip generation rates. Again, this outcome appeared to be independent of whether the models in question represented either major metropolitan areas or smaller urban and rural areas.
How are these variables used in the model?
In general, zonal variables describing employment or industrial land uses are used to estimate trip attraction figures, and variables describing residential land uses are used to estimate trip production figures. The Santa Clara County Transportation Authority uses several of these zonal variables for running attraction regressions.
Data sources used in the model:
In general, respondents indicated that most of the zonal data used for trip generation came from their respective regional planning agencies (e.g., ABAG, SCAG, etc.) or Census data. Those using ITE trip generation rates used the ITE trip generation manual.

4.4.2 Please list your principle data sources for economic forecasts. Also provide us with the types of data that these sources provide to assist you in making forecasts and a brief description of how you use these forecasts.

Many respondents indicated that their respective agencies based their economic forecasts on projections published by their Regional Planning Agencies. This was true particularly of agencies representing large metropolitan areas like the San Francisco Bay Area and the San Diego area.

Agencies from smaller urban and rural areas often indicated that they relied more on General Plan specifications, especially for forecasting growth in employment and specific land uses, such as retail and non-retail.

Several agencies indicated that they based regional population, housing, and employment projections on data from the California Department of Finance (DOF). The line between large metropolitan areas and smaller urban and rural areas was less defined in these cases, as agencies representing both types of areas identified DOF as a data source.

In some cases, agencies use different data sources – and forecasting methods – depending on whether they are looking at the regional or sub-regional level. This was the case with SANDAG.

Other agencies rely on various data sources including research from local universities, as well as 1990 Census data.

4.4.3 Please provide any additional information describing some unique aspect of your modeling approach not provided. For example, you may elaborate on any economic or land use models used to arrive at assumptions for forecast years.

The six responses received for this question are presented below. Each entry includes the name of the corresponding agency and its respective reply, as provided by its representative.

- MTC – "Please refer to the following website for a complete description of MTC's travel demand modeling approach: www.mtc.ca.gov/datamart"

- Tahoe Regional Planning Agency (TRPA) –"it is anticipated that the 1995 base year will be the last for Lake Tahoe. The socio-economic information is based on a 1974 survey. Neither the resources nor the need exist for updating the model for future base years. TRPA will be updating to an airshed model in coming years."

- Butte County Association of Governments (BCAG) – "the BCAG county-wide model -- developed using MINUTP V.98 – is rather straight forward. Input files were developed using each of the adopted General Plans, in consultation with BCAG's Transportation Advisory Committee. BCAG's zonal structure is based on the 1990 Census block groups. Future model development will be coordinated with ArcView or some GIS using GPS technology. All land use information will be contained on this system and will be used for the next base update after the 2000 Census. This model is used as a tool in a regional context."

- "SANDAG uses many zones with detailed transportation networks to provide sub-regional input for the larger, regional model. Transportation models are used for many local planning studies."

- The Tulare County Association of Governments keeps an air quality model that doesn't change (in order to maintain conformity), and a land use model that is updated on a continuous basis.

- SCAG's model uses taxable sales data from the California State Board of Equalization to forecast transportation revenues. Income distribution data is taken from the California Franchise Board in order to perform transportation equity analysis. Auto operation cost data, for mode choice model, are taken from AAA, FHWA, and the General Services Administration.

5. CONCLUSIONS

The results obtained from the in-depth travel demand modeling surveys confirmed many pre-conceptions from the consultant team, mainly relating to the disparate nature of models used, horizon years, and incorporation of modes other than highway:

- Agencies plan using different base and horizon years

- Some regions have multiple models (e.g., MTC, SCAG)

- Transit is not addressed as fully as highway and road networks. Major metropolitan area models address transit, albeit to different degrees across agencies

- Some agencies forecast truck/commercial vehicle activity, although relatively few account for this mode directly in their models or through a separate freight model. Agencies that forecast truck/commercial vehicle activity tend to base figures on historical data from outside sources

- Forecasting assumptions vary significantly. For example, growth rate assumptions for many variables (e.g., employment, population, etc.) are likely to differ between county, regional, and statewide models.

The travel demand modeling process is extremely dynamic. Travel forecasting is not an exact science and as such constantly scrutinized by the modelers themselves as well as by downstream users of the data. Regional models are constantly being "tweaked" as part of regular updates or in response to construction projects and inconsistencies noted by users. The prospect of attaining increased consistency among methods and methodologies will be challenging due to the inherent differences between the regions and agencies, as well as their respective responsibilities. Performance measures can help steer regions towards more consistent travel demand methodologies, though achieving state-wide standardization is unrealistic at this time.

APPENDIX A
SURVEY INSTRUMENT

STATEWIDE TRAVEL DEMAND MODEL SURVEY

This survey will be used to develop an inventory of transportation demand models and modeling assumptions used by regional agencies throughout the State. This effort is part of the California Transportation System Performance Measurement initiative that started in 1998, led by the Business, Transportation and Housing Agency.

The survey has four parts. First, it asks some general questions about the travel demand model(s) that you use. It then addresses the "supply-side" elements of your model (e.g., transit routes, streets and roads). The survey also asks about "demand-side" elements (e.g., market segments, trip types). Finally, the survey asks you to discuss assumptions that you make when developing your forecasts and to list the data sources that you use.

Thank you for your prompt response and your help in this effort. We must receive all surveys by June 15, 1999. Please send the completed survey to:

Bill McCullough
101 California Street, Suite 3300
San Francisco, California 94111

Or fax it to:
Bill McCullough
415-627-4283

You can contact Bill if you have any questions or comments at 415-281-4904.

General Agency Contact Information

Please complete the following information about your agency.

1. Agency Name: ____
2. Contact Person: ____
3. Telephone: ___________________________
4. Email: _______________________________

I. General Model Information

1. What type of modeling software system(s) do you use (e.g., EMME/2, TRANPLAN, MINUTP)? Please list all that apply.

2. What is the official base year(s) for your model(s)? _________ ________ _________

3. When was the last time that your base year model(s) were updated (MO/YR)? _____

4. How often do you update your official base year(s)? __________

5. What are your official horizon years? ________ ________ ________ ________

6. What time periods do you model (Check all that apply)?

Base Year	Forecast Years	Weekday	Weekend	Time Period
◊	◊	◊	◊	AM Peak 1 Hour
◊	◊	◊	◊	PM Peak 1 Hour
◊	◊	◊	◊	AM Peak Period. How many hours in the model? ____
◊	◊	◊	◊	PM Peak Period. How many hours in the model? ____
◊	◊	◊	◊	Midday. How many hours in the model? ____
◊	◊	◊	◊	Daily
◊	◊	◊	◊	Other. Please Explain.

II. Supply Information

Now we would like to ask you some questions about the types of information that your model uses to describe the supply or level of services that are available to travelers.

1. At what level of detail does you model network represent streets, roads, and transit?

Network Classification	All Included in Model	Most Included	Some Included	None Included
Freeways & Expressways	◊	◊	◊	◊
HOV Lanes as separate links?	◊	◊	◊	◊
Other Principal Arterials	◊	◊	◊	◊
Major Collectors	◊	◊	◊	◊
Minor Collectors	◊	◊	◊	◊
Other Streets/Roads	◊	◊	◊	◊
Commuter/Urban Rail	◊	◊	◊	◊
Other Rail Lines	◊	◊	◊	◊
Bus Routes	◊	◊	◊	◊

Describe Other Streets/Roads Here.

____

____

____

2. What modes are represented in your model (Check all that apply)?

◊ Auto – Generalized (i.e., not classified by occupancy or HOV facility)
◊ Auto – Single Occupancy Vehicle (SOV)
◊ Auto – High Occupancy Vehicle (HOV 2-Person)
◊ Auto – HOV 3+ Persons
◊ Transit – Generalized (i.e., not mode specific. Includes both bus and rail.)
◊ Transit – Bus
◊ Transit – Combined Rail (Urban and Commuter)
◊ Transit – Urban Rail (Light Rail, Subway, Heavy Rail)
◊ Transit – Commuter Rail (e.g., Amtrak, Metrolink, Coaster, CalTrain, ACE)

Other. Please describe. ____

III. Demand Information

Please provide us with information about how your model segments trips or travel markets.

1. What trip types does your modeling system produce:

◊ Person Trips ◊ Vehicle Trips ◊ Both

2. What type of trip generation analysis do you perform (e.g., cross-classification, opportunity, regression, other)?

3. What type of trip distribution model do you use (e.g., gravity, opportunity, other)?

4. What trip purposes does your model account for (Check all that apply)?

◊ Home-based Work
◊ Home-based Shopping
◊ Home-based Other
◊ Non-Home based Shopping
◊ Non-Home based Other
◊ Other classifications. Please explain.

5. Can your model provide other market segmentation information after trips have been assigned? For example, can the model stratify trip types by income or other socio-economic classification? Please explain.

6. How do you account for trucks/commercial vehicle travel activity? Describe.

IV. Economic/Demographic/Forecast Assumptions

We are interested in learning more about what variables you use in developing model forecasts. Please help us by completing the questions below.

1. The following tables list commonly used variables in mode split, assignment, and trip generation modules. Please fill out the tables to the best of your knowledge. These lists are not all inclusive, so there is space available to add additional information.

Mode Split/Network Assignment

Variable	Do Not Use	Describe How Used in the Model	Data Source(s) for Forecast Years (Please be specific)
Parking cost	◊		
Fuel cost	◊		
Vehicle operating cost	◊		
Toll cost	◊		
Bus fares	◊		
Travel time by auto	◊		
Travel time by bus	◊		
Auto ownership	◊		
Household income	◊		
Gender	◊		
Other Variables Used in Mode Split Model (Not listed above.)			

Trip Generation

Variable	Do Not Use	Describe How Used in the Model	Data Source(s) for Forecast Years (Please be specific)
Personal			
Gender	◊		
Age	◊		
Personal income	◊		
Occupation	◊		
Other:			
Household			
Population	◊		
Number of households	◊		
Household type	◊		
Family size	◊		
Auto ownership	◊		
Children: number & age	◊		
Household income	◊		
Other:			
Zonal			
Land-use	◊		
Residential density	◊		
Accessibility	◊		
Retail employment	◊		
Non-retail employment	◊		
Total employment	◊		
CBD/Non-CBD	◊		
Dwelling units	◊		
Retail/Non-retail areas	◊		
ITE Trip generation	◊		
Other:			
Network Characteristics			
Level of service	◊		
Other Variables Used in Forecasting			

2. Please list your principal data sources for economic forecasts. Also provide us with the types of data that these sources provide to assist you in making forecasts and a brief description of how you use these forecasts. Please use the back of this survey if not enough space is provided below.

Data Source	Data Provided/ How Used

3. Please provide any additional information describing some unique aspect of your modeling approach not provided above. For example, you may elaborate on any economic or land-use models used to arrive at assumptions for forecast years.

THANK YOU VERY MUCH FOR YOUR HELP IN PROVIDING US WITH THIS VALUABLE INFORMATION!

APPENDIX B
KEY OF SURVEY RESULTS

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	Survey Respondent	1.1 Model Software	1.2 Base Year	1.3 Last Base Year Update	1.4 Frequency of Base Year Model Update	1.5 Official Horizon Years						
Survey No.							First Horizon Year	Subsequent Forecast Years					
	I.0.1	I.0.2	I.1	I.2	I.3	I.4	I.5						
1	Kern Council of Governments	Michelle Bitner	MINUTP; changing to TP+ late summer	1994	1995	as needed	2020						
2	Metropolitan Transportation Commission (MTC)	Chuck Purvis	MINUTP; TP+/VIPER	1990	1999	5 years	1995	1998	2000	2005	2010	2015	2020
3	Transportation Agency for Monterey County	Doug Bilse	AMBAG does all modeling										
4	Tahoe Regional Planning Agency	Jim Allison	TRANPLAN	1995	1996	5 years	2001	2006	2016				
5	California Energy Commission	Leigh Stamets	CALCARS; California energy demand freight and transit models	recent year	1997	every year or so	20 year forecast						
6	Butte County Association of Governments	Chris Devine/Ivan Garcia	MINUTP	1998	1998	As necessary (not to exceed 5 years)	2008	2018					
7	Santa Clara County (Center for Urban Analysis)	Frank Lickfed	TRANPLAN	1990	1997	Only when there is a damage of underlying data or a structural damage	2005	2015	2020	2025			
8	Orange County Transportation Authority (OCTA)	Ron Taira	TRANPLAN	1990, 1997	1998	4 years	2005	2010	2015	2020			
9	San Diego Association of Governments (SANDAG)	Bill McFarlane	TRANPLAN/ARC info	1995	on-going	3-5 years	1995	2000	2005	2010	2015	2020	
10	California Air Resources Board (CARB)	Ed Yotter	We use modeling data from all COGs/MPOs to develop statewide emissions estimates.			1996	2020						
11	City of Modesto	Helen Wang	MINUTP (TP+)	1990	1995	about 10 years	2025						
12	Tulare County Association of Governments	Gary Mills	MINUTP;TP+/Viper	1990	1995	Every 5 years	2018	2020	2025	2030			
13	Council of Fresno County Governments	Mike Bitner/Colby Morrow	MINUTP, but we are converting to TP+	1990	1994	At least every 10 years	2018 - for the RTP	2020 - for most traffic studies					
14	Merced County Association of Governments	Matt Fell	MINUTP, moving to TP+/Viper	1990	1994	2-5 years	2010	2020					
15	San Joaquin Council of Governments	Kim Kloeb	MINUTP, TP+	1996	1996	As needed	2020						
16	Santa Barbara County Association of Governments (SBCAG)	William Yim	System 2	1990	1998	3-4 years	1999	2005	2015	2020			
17	Sacramento Area Council of Governments (SACOG)	Bruce Griesenbeck	MINUTP	1997	1999	3+ years	2022						
18	Southern California Association of Government (SCAG)	Deng-Bang Lee	TRANPLAN; EMME/2; TRANSCAD	1994	1996	3-4 years	2000	2010	2020				
19	Ventura County Transportation Commission	Steve De George	TRANPLAN	1994	1999	Every 5 years	2020						

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	1.6 Time Period Being Modeled: AM Peak 1 Hour				1.6 Time Period Being Modeled: PM Peak 1 Hour				1.6 Time Period Being Modeled: AM Peak Period Other				
Survey No.		Base Year	Forecast Years	Weekday	Weekend	Base Year	Forecast Years	Weekday	Weekend	Base Year	Forecast Years	Weekday	Weekend	No. of Hours
	I.0.1	I.6.a.1	I.6.a.2	I.6.a.3	I.6.a.4	I.6.b.1	I.6.b.2	I.6.b.3	I.6.b.4	I.6.c.1	I.6.c.2	I.6.c.3	I.6.c.4	I.6.c.5
1	Kern Council of Governments									Y	Y	Y		2
2	Metropolitan Transportation Commission (MTC)									Y	Y	Y		2
3	Transportation Agency for Monterey County													
4	Tahoe Regional Planning Agency													
5	California Energy Commission													
6	Butte County Association of Governments													
7	Santa Clara County (Center for Urban Analysis)	Y	Y	Y		Y	Y	Y		Y	Y	Y		3
8	Orange County Transportation Authority (OCTA)	Y	Y	Y		Y	Y	Y		Y	Y	Y		3
9	San Diego Association of Governments (SANDAG)									Y	Y	Y		3
10	California Air Resources Board (CARB)									Y	Y	Y		3
11	City of Modesto													
12	Tulare County Association of Governments									Y	Y	Y		3
13	Council of Fresno County Governments	Y	Y	Y		Y	Y	Y		Y	Y	Y		
14	Merced County Association of Governments													
15	San Joaquin Council of Governments													
16	Santa Barbara County Association of Governments (SBCAG)													
17	Sacramento Area Council of Governments (SACOG)	Y	Y	Y		Y	Y	Y		Y	Y	Y		
18	Southern California Association of Government (SCAG)									Y	Y	Y		3
19	Ventura County Transportation Commission									Y	Y	Y		3

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	1.6 Time Period Being Modeled: PM Peak Period Other					1.6 Time Period Being Modeled: Midday					1.6 Time Period Being Modeled: Daily			
Survey No.		Base Year	Forecast Years	Weekday	Weekend	No. of Hours	Base Year	Forecast Years	Weekday	Weekend	No. of Hours	Base Year	Forecast Years	Weekday	Weekend
	I.0.1	I.6.d.1	I.6.d.2	I.6.d.3	I.6.d.4	I.6.d.5	I.6.e.1	I.6.e.2	I.6.e.3	I.6.e.4	I.6.e.5	I.6.f.1	I.6.f.2	I.6.f.3	I.6.f.4
1	Kern Council of Governments	Y	Y	Y		3	Y	Y	Y		2	Y	Y	Y	
2	Metropolitan Transportation Commission (MTC)											Y	Y	Y	
3	Transportation Agency for Monterey County														
4	Tahoe Regional Planning Agency											Y	Y	Y	
5	California Energy Commission														
6	Butte County Association of Governments											Y	Y	Y	
7	Santa Clara County (Center for Urban Analysis)	Y	Y	Y		3									
8	Orange County Transportation Authority (OCTA)	Y	Y	Y		4	Y	Y	Y		6	Y	Y	Y	
9	San Diego Association of Governments (SANDAG)	Y	Y	Y		3	Y	Y	Y		18				
10	California Air Resources Board (CARB)	Y	Y	Y		3	Y	Y	Y		6	Y	Y	Y	
11	City of Modesto											Y	Y	Y	
12	Tulare County Association of Governments	Y	Y	Y		3						Y	Y	Y	
13	Council of Fresno County Governments	Y	Y	Y			Y	Y	Y			Y	Y	Y	
14	Merced County Association of Governments											Y	Y		
15	San Joaquin Council of Governments														
16	Santa Barbara County Association of Governments (SBCAG)											Y	Y	Y	
17	Sacramento Area Council of Governments (SACOG)	Y	Y	Y								Y	Y	Y	
18	Southern California Association of Government (SCAG)	Y	Y	Y		4	Y	Y	Y		6				
19	Ventura County Transportation Commission	Y	Y	Y		2						Y	Y	Y	

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	1.6 Time Period Being Modeled: Other				
Survey No.		Base Year	Forecast Years	Weekday	Weekend	Notes
	I.0.1	I.6.g.1	I.6.g.2	I.6.g.3	I.6.g.4	I.6.g.5
1	Kern Council of Governments					
2	Metropolitan Transportation Commission (MTC)					
3	Transportation Agency for Monterey County					
4	Tahoe Regional Planning Agency					
5	California Energy Commission	Y	Y			Annual energy, vehicle and VMT demand
6	Butte County Association of Governments					Note: Model is used for specific studies in which PM P/C hour is calculated or turn moves. (Model is used as a basis.)
7	Santa Clara County (Center for Urban Analysis)	Y	Y	Y		Transit. 4 period - AM peak, PM peak, Mid-day, evening
8	Orange County Transportation Authority (OCTA)					
9	San Diego Association of Governments (SANDAG)					
10	California Air Resources Board (CARB)	Y	Y	Y		Night time 2 @ 6 hrs. each = 12
11	City of Modesto					1990 Base, 2025 Forecast
12	Tulare County Association of Governments					
13	Council of Fresno County Governments					
14	Merced County Association of Governments					
15	San Joaquin Council of Governments					
16	Santa Barbara County Association of Governments (SBCAG)					Peak time model available per use.
17	Sacramento Area Council of Governments (SACOG)		Off-peak (daily-AM per-PM per)			
18	Southern California Association of Government (SCAG)	Y	Y	Y		Nights -- 11 hrs
19	Ventura County Transportation Commission					

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	2.1 At What Level of Detail Does Your Model Network Represent Streets, Roads, and Transit?									
Survey No.		Freeways & Expressways	HOV Lanes as separate links	Other Principal Arterials	Major Collectors	Minor Collectors	Other Streets/Roads	Commuter/ Urban Rail	Other Rail Lines	Bus Routes	Other Streets/Roads
	I.0.1	II.1.a	II.1.b	II.1.c	II.1.d	II.1.e	II.1.f	II.1.g	II.1.h	II.1.I	II.1.j
1	Kern Council of Governments	None included	None included	None included	None included	None included	None included	None included	None included	None included	
2	Metropolitan Transportation Commission (MTC)	All included in Model	All included in Model	All included in Model	Most included	Some included	None included	All included in Model	All included in Model	Most included	
3	Transportation Agency for Monterey County										
4	Tahoe Regional Planning Agency	None included	None included	All included	All included	Most included	Some included	None included	None included	None included	Only if they represent the lmkage to the
5	California Energy Commission	None included	None included	None included	None included	None included	None included	Most Included	None included	None included	
6	Butte County Association of Governments	All included	None included	None included	Most included	Most included	Some included	None included	None included	None included	
7	Santa Clara County (Center for Urban Analysis)	All included	All included	All included	All included	Most included	Some included	All included	None included	All included	
8	Orange County Transportation Authority (OCTA)	All included	All included	All included	All included	Most included	Some included	All included	None included	All included	Smart-Streets, Freeway ramps and connectors,
9	San Diego Association of Governments (SANDAG)	All included	All included	All included	All included	All included	Some included	All included	All included	All included	
10	California Air Resources Board (CARB)	None included	None included								We are developing the capability over the next year to
11	City of Modesto	All included	None included	All included	All included	Most included	None included	None included	None included	None included	
12	Tulare County Association of Governments	All included	None included	Most included	Most included	Some included	None included	None included	None included	None included	Centroid connectors may include
13	Council of Fresno County Governments	All included	None included	All included	All included	Most included	Some included	None included	None included	None included	Local collectors
14	Merced County Association of Governments	All included	None included	All included	Most included	Some included	None included	None included	None included	None included	
15	San Joaquin Council of Governments	All included	All included	All included	Most Included	Some included	None included	None included	None included	None included	
16	Santa Barbara County Association of Governments (SBCAG)	All included	None included	All included	All included	Most included	Some included	None included	None included	None included	
17	Sacramento Area Council of Governments (SACOG)	All included	All included	All included	Most included	Some included	None included	All included	None included	Most included	
18	Southern California Association of Government (SCAG)	All included	All included	All included	All included	Some included	Some included	All included	All included	All included	Toll Roads will be included in next base year, 1997
19	Ventura County Transportation Commission	All included	None included	All included	All included	Most included	Some included	None included	None included	None included	

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	2.2 What Modes are Represented in Your Model?									
Survey No.		Auto-Generalized	Auto-Single Occupancy	Auto-High Occupancy	Auto-HOV 3+	Transit-Generalized	Transit-Bus	Transit-Combined Rail	Transit-Urban Rail	Transit-Commuter Rail	Other Modes
	I.0.1	II.2.a	II.2.b	II.2.c	II.2.d	II.2.e	II.2.f	II.2.g	II.2.h	II.2.I	II.2.j
1	Kern Council of Governments										
2	Metropolitan Transportation Commission (MTC)		Y	Y	Y	Y	Y		Y	Y	
3	Transportation Agency for Monterey County										
4	Tahoe Regional Planning Agency	Y									
5	California Energy Commission	Y					Y		Y	Y	
6	Butte County Association of Governments	Y									
7	Santa Clara County (Center for Urban Analysis)		Y	Y	Y		Y		Y		Company shuttle and mode choice in progress - light rail, heavy rail, bus
8	Orange County Transportation Authority (OCTA)		Y	Y	Y		Y		Y	Y	Tolls for SOV, HOV (2), HOV (3+), Transit-Express
9	San Diego Association of Governments (SANDAG)		Y	Y			Y	Y			
10	California Air Resources Board (CARB)										VMT by speed provided by COG/MPO.
11	City of Modesto	Y									
12	Tulare County Association of Governments	Y									
13	Council of Fresno County Governments	Y									
14	Merced County Association of Governments	Y									
15	San Joaquin Council of Governments	Y									
16	Santa Barbara County Association of Governments (SBCAG)	Y		Y		Y					
17	Sacramento Area Council of Governments (SACOG)		Y	Y	Y						Transit - drive access, transit-walk access - Non-motorized - walk, bicycle
18	Southern California Association of Government (SCAG)		Y	Y	Y		Y	Y			Maglev trains are planned for connecting airports in 2020
19	Ventura County Transportation Commission	Y									

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	3.1 Trip Type			3.2 What Type of Trip Generation Model do You Use?		
Survey No.		Person Trips	Vehicle Trips	Both	Type	Type	Type
	I.0.1	III.1.a	III.1.b	III.1.c	III.2.a	III.2.b	III.2.c
1	Kern Council of Governments		Y		Trip generation is done outside the model in a Fortran program.		
2	Metropolitan Transportation Commission (MTC)	Y	Y	Y	Regression	Cross-classification	Trip rates
3	Transportation Agency for Monterey County						
4	Tahoe Regional Planning Agency			Y	Cross-classification		
5	California Energy Commission						
6	Butte County Association of Governments	Y					
7	Santa Clara County (Center for Urban Analysis)	Y			Regression		
8	Orange County Transportation Authority (OCTA)			Y	Cross-classification		
9	San Diego Association of Governments (SANDAG)			Y	Trip rate		
10	California Air Resources Board (CARB)		Y		COG/MPO provided		
11	City of Modesto				Regression		
12	Tulare County Association of Governments	Y					
13	Council of Fresno County Governments			Y	Model uses proportional smoothing technique		
14	Merced County Association of Governments		Y				
15	San Joaquin Council of Governments		Y				
16	Santa Barbara County Association of Governments (SBCAG)			Y	Cross-classification		
17	Sacramento Area Council of Governments (SACOG)			Y	Cross-classification		
18	Southern California Association of Government (SCAG)			Y	Cross-classification	Regression	
19	Ventura County Transportation Commission	Y			Regression		

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	3.3 Trip Distribution Model		
Survey No.		Type	Type	Type
	I.0.1	III.3.a	III.3.b	III.3.c
1	Kern Council of Governments	Gravity		
2	Metropolitan Transportation Commission (MTC)	Gravity		
3	Transportation Agency for Monterey County			
4	Tahoe Regional Planning Agency	Gravity		
5	California Energy Commission			
6	Butte County Association of Governments	Gravity		
7	Santa Clara County (Center for Urban Analysis)	Gravity - moving to a regression form		
8	Orange County Transportation Authority (OCTA)	Gravity (current)	New model (available in 3 months) use "logsum" composite	Independence for HBW trips - gravity for other trip purposes
9	San Diego Association of Governments (SANDAG)	Gravity		
10	California Air Resources Board (CARB)	COG/MPO provided		
11	City of Modesto	Gravity		
12	Tulare County Association of Governments	Gravity		
13	Council of Fresno County Governments	Gravity		
14	Merced County Association of Governments	Gravity		
15	San Joaquin Council of Governments	Gravity		
16	Santa Barbara County Association of Governments (SBCAG)	Gravity		
17	Sacramento Area Council of Governments (SACOG)	Gravity		
18	Southern California Association of Government (SCAG)	Gravity		
19	Ventura County Transportation Commission	Gravity		

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	3.4 What Trip Purposes Does Your Model Account for?						3.5 Other Market Segmentation Capabilities?
Survey No.		Home-based Work	Home-based Shopping	Home-based Other	Non Home-based Shopping	Non Home-based Other	Other Classifications	
	I.0.1	III.4.a	III.4.b	III.4.c	III.4.d	III.4.e	III.4.f	III.5
1	Kern Council of Governments	Y	Y	Y	Y	Y	HBO Elementary School, HBO High School, HBO College, truck trips,	No
2	Metropolitan Transportation Commission (MTC)	Y	Y				Non-homebased; homebased social recreation; homebased school stratified by grade school; high school; college	Work trip mode choice is market segmented by AO level and income . HBSH and HBSR trips are segmented by
3	Transportation Agency for Monterey County							
4	Tahoe Regional Planning Agency	Y	Y	Y	Y		Home based recreation as well as visitor HBR, HBO, NHB - also Res/Vis external and through trips	No
5	California Energy Commission							Personal vehicle energy and travel whose modified by income and number of workers and sizes of household.
6	Butte County Association of Governments	Y		Y		Y		Not at this time
7	Santa Clara County (Center for Urban Analysis)	Y	Y	Y			All non-license based university/community college	No
8	Orange County Transportation Authority (OCTA)	Y	Y	Y		Y	Home-based work at home	HBW trips are segmented into low, medium, and high income categories. Auto separated by DA, HOV (2), HOV
9	San Diego Association of Governments (SANDAG)	Y	Y	Y		Y	College, K-12, Work-other, Airport, Visitor	Can if requested, not standard output
10	California Air Resources Board (CARB)							
11	City of Modesto	Y	Y	Y		Y	Other-work	No
12	Tulare County Association of Governments	Y	Y	Y	Y	Y		No
13	Council of Fresno County Governments	Y	Y	Y		Y	Non home based work	No.
14	Merced County Association of Governments	Y	Y	Y		Y		No
15	San Joaquin Council of Governments	Y	Y	Y	Y	Y	Y	Never Tried
16	Santa Barbara County Association of Governments (SBCAG)	Y	Y	Y		Y	Home based school, non home based work, IX/XI, Visitor	No
17	Sacramento Area Council of Governments (SACOG)	Y	Y	Y			Work-other, other-other, commercial vehicle, school	With great difficulty
18	Southern California Association of Government (SCAG)	Y	Y	Y		Y	New model will have home-based school	Socio-economic character of trips are tested after trips have been assigned
19	Ventura County Transportation Commission	Y	Y	Y	Y	Y		No

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	3.6 Accounting for Truck/Commercial Vehicle Activity	4.1 Mode Split/Network Assignment -- Variables					
Survey No.			Parking Cost	Parking Cost Data Source	Fuel Cost	Fuel Cost Data Source	Vehicle Operating Cost (VOC)	VOC Data Source
	I.0.1	III.6	IV.1.1.a	IV.1.1.b	IV.1.2.a	IV.1.2.b	IV.1.3.a	IV.1.3.b
1	Kern Council of Governments	There is a truck trip in the model but it is not accurate and not used to provide any information			Do not use		Do not use	
2	Metropolitan Transportation Commission (MTC)	Truck trip generation and distribution models are applied for small, medium, and "combination" truck trip types.	Included - see model		Included - documentation		Included - http://www.mtc.ca.gov/datamart/	
3	Transportation Agency for Monterey County							
4	Tahoe Regional Planning Agency	They are negotiable	Do not use		Do not use		Do not use	
5	California Energy Commission	Freight model accounts for heavy tracks by commodity and CALCARS has commercial fleet model for light duty trucks.			Vehicle choice considers fuel operating cost	CEC Forecast	Affects ridership in transit model	
6	Butte County Association of Governments	Account after the fact by simply assuming or applying a % based on the route and its characteristics (I.e. fwy, major, etc.)						
7	Santa Clara County (Center for Urban Analysis)	Included in capacity consideration	MTC mode for HBO work	MTC and local sources	Do not use - MTC non-work modes, Feb. 88			MTC
8	Orange County Transportation Authority (OCTA)	Not modeled directly. Will incorporate new truck model developed for SCAG - upon SCAG's review and acceptance.	Used in calculation of auto's LOS (level of service)	SCAG	Do not use		Used in calculation of LOS (level of service)	SCAG
9	San Diego Association of Governments (SANDAG)	Factoring of other - other trips to match observed VMT.	Mode Split	CBD survey	Mode Split	Travel factors	Mode Split	FHWA
10	California Air Resources Board (CARB)	COG/MPO provided						
11	City of Modesto	Trucks/commercial vehicle travel activity is accounted by trip generation and attraction with employee numbers in retail, service and	Set terminal times (parking) for CBD	Same as base year				
12	Tulare County Association of Governments	Use survey data and apply to model output	Do not use		Do not use		Do not use	
13	Council of Fresno County Governments	We do not.	Do not use		Do not use		Do not use	
14	Merced County Association of Governments	Does not account for them.	Do not use					
15	San Joaquin Council of Governments	No						
16	Santa Barbara County Association of Governments (SBCAG)	Truck trips are part of external trip estimation based on historical truck traffic data from Caltrans						
17	Sacramento Area Council of Governments (SACOG)	Separate purpose, split into 3+ axle vehicles, and all other vehicles	Mode Choice HBW	Early 90's		Combined mode choice and all purposes.		
18	Southern California Association of Government (SCAG)	Currently using ARB data for air quality analysis -- new model will incorporate directly	Auto disutility	Regression	Included in auto operating cost	Total VOC same as 1993 base yr	Auto disutility	Total VOC same as 1993 base yr
19	Ventura County Transportation Commission	No	Do not use		Do not use		Do not use	

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Mode Split/Network Assignment -- Variables							
Survey No.		Toll Cost	Toll Cost Data source	Bus fares	Bus Fare Data Source	Travel Time by Auto	Travel Time by Auto Data Source	Travel Time by Bus	Travel Time by Bus Data Source
	I.0.1	IV.1.4.a	IV.1.4.b	IV.1.5.a	IV.1.5.b	IV.1.6.a	IV.1.6.b	IV.1.7.a	IV.1.7.b
1	Kern Council of Governments	Do not use		Do not use			Provided by consultant	Do not use	
2	Metropolitan Transportation Commission (MTC)	Included		Included		Included		Included	
3	Transportation Agency for Monterey County								
4	Tahoe Regional Planning Agency	Do not use		Do not use		The skims - also by TAZ to TAZ		Do not use	
5	California Energy Commission			Affects ridership in transit model		Affects ridership in transit model		Affects ridership in transit model	
6	Butte County Association of Governments								
7	Santa Clara County (Center for Urban Analysis)		MTC		MTC		Network		Network/schedule
8	Orange County Transportation Authority (OCTA)	Used in calculation of LOS (level of service)	TCA	Used in calculation of LOS (level of service)	OCTA/MTA	Used in calculation of LOS (level of service) and in determination of	Model	Used in calculation of LOS and in shortest path calculation	Model
9	San Diego Association of Governments (SANDAG)	TD distribution/ Mode split/ Network assignment	Toll schedule	Mode Split	Transit schedule	TD distribution/ Mode split/ Network assignment	Speed limit/signals	Mode Split/Network assignment	Transit schedule
10	California Air Resources Board (CARB)								
11	City of Modesto					Turn penalties	Same as base year		Single family with 0,1,2+ vehicles in TG
12	Tulare County Association of Governments	Do not use		Do not use		Time	Model output	Do not use	
13	Council of Fresno County Governments	Do not use		Do not use		Trip distribution		Do not use	
14	Merced County Association of Governments								
15	San Joaquin Council of Governments								
16	Santa Barbara County Association of Governments (SBCAG)					Impedance			
17	Sacramento Area Council of Governments (SACOG)				Mode choice, all purposes.		Mode choice, all purposes.		Mode choice, all purposes.
18	Southern California Association of Government (SCAG)	Auto disutility, highway assignment	1993 base year	Transit disutility	Same as base year	Auto disutility	Future highway network	Transit disutility	Same as base year
19	Ventura County Transportation Commission	Do not use		Do not use		Do not use		Do not use	

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Mode Split/Network Assignment -- Variables							
Survey No.		Auto Ownership	Auto Ownership Data Source	Household Income	Household Income Data Source	Gender	Gender Data Source	Other Variable 1	Other Variable 1Data Source
	I.0.1	IV.1.8.a	IV.1.8.b	IV.1.9.a	IV.1.9.b	IV.1.10.a	IV.1.10.b	IV.1.11.a	IV.1.11.b
1	Kern Council of Governments	Do not use		HBW trips	Census and provided by consultant	Do not use			
2	Metropolitan Transportation Commission (MTC)	Included		Included				See documentation	
3	Transportation Agency for Monterey County								
4	Tahoe Regional Planning Agency	Do not use		Satisfied by low, medium, high by recognized divisions					
5	California Energy Commission	Predicted effects VMT	DMV registration database	Effects vehicle choice and VMT	CEC Forecast (DRI)			Travel time	
6	Butte County Association of Governments								
7	Santa Clara County (Center for Urban Analysis)		MTC controls		ABAG	Do not use		Workers/HH	ABAG
8	Orange County Transportation Authority (OCTA)	Autos per person used in utility	Auto ownership Model	Used in calculation of HBW	SCAG/cal state fullertin	Do not use		Population density - utility calculation	SCAG
9	San Diego Association of Governments (SANDAG)	Do not use		Mode Split	Census	Do not use			
10	California Air Resources Board (CARB)							COG/MPO developed	
11	City of Modesto	Same as base year							
12	Tulare County Association of Governments	Single family (sf) 2+,1,0 Multi family (mf) 2+,1,0	Census	Do not use		Do not use			
13	Council of Fresno County Governments	Socioeconomic input		Do not use		Do not use			
14	Merced County Association of Governments								
15	San Joaquin Council of Governments								
16	Santa Barbara County Association of Governments (SBCAG)			Classified into 4 levels	CTPP data/SBAG referral growth forecast				
17	Sacramento Area Council of Governments (SACOG)		Mode choice, all purposes.		Mode choice, all purposes.			Pedestrian environment factor	Mode choice
18	Southern California Association of Government (SCAG)	Market segmentation	SE forecast	Value of time	SE Forecast	Do not use		zonal workers	SE Forecast
19	Ventura County Transportation Commission	Do not use		Do not use		Do not use			

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Mode Split/Network Assignment -- Variables					
Survey No.		Other Variable 2	Other Variable 2 Data Source	Other Variable 3	Other Variable 3 Data Source	Other Variable 4	Other Variable 4 Data Source
	I.0.1	IV.1.12.a	IV.1.12.b	IV.1.13.a	IV.1.13.b	IV.1.14.a	IV.1.14.b
1	Kern Council of Governments						
2	Metropolitan Transportation Commission (MTC)						
3	Transportation Agency for Monterey County						
4	Tahoe Regional Planning Agency						
5	California Energy Commission	Commodity type between truck and rail					
6	Butte County Association of Governments						
7	Santa Clara County (Center for Urban Analysis)	Residential density	ABAG and local sources	Employment density	ABAG and local sources		
8	Orange County Transportation Authority (OCTA)	Employment density - utility calculation	SCAG	Household size - utility calculation	SCAG	XY distance - used for non-motorized mode	based on coordinates
9	San Diego Association of Governments (SANDAG)						
10	California Air Resources Board (CARB)						
11	City of Modesto						
12	Tulare County Association of Governments						
13	Council of Fresno County Governments						
14	Merced County Association of Governments						
15	San Joaquin Council of Governments						
16	Santa Barbara County Association of Governments (SBCAG)						
17	Sacramento Area Council of Governments (SACOG)	Carpool partner density		Bike/walk distance			
18	Southern California Association of Government (SCAG)	zonal licensed drivers	SE Forecast	Zonal acreage	SE Forecast		
19	Ventura County Transportation Commission						

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Personal									
Survey No.		Gender	Gender Data Source	Age	Age Data Source	Personal Income	Personal Income Data Source	Occupation	Occupation Data Source	Other	Other Data Source
	I.0.1	IV.2.1.a	IV.2.1.b	IV.2.2.a	IV.2.2.b	IV.2.3.a	IV.2.3.b	IV.2.4.a	IV.2.4.b	IV.2.5.a	IV.2.5.b
1	Kern Council of Governments										
2	Metropolitan Transportation Commission (MTC)			Do not use - HBO School models						Industry is used in several models	
3	Transportation Agency for Monterey County										
4	Tahoe Regional Planning Agency	Do not use		Do not use		Do not use		Do not use			
5	California Energy Commission					Effect VMT					
6	Butte County Association of Governments										
7	Santa Clara County (Center for Urban Analysis)	Do not use		Do not use		Do not use		Do not use			
8	Orange County Transportation Authority (OCTA)	Do not use		Do not use		Do not use		Do not use			
9	San Diego Association of Governments (SANDAG)	Do not use		Do not use		Do not use		Do not use			
10	California Air Resources Board (CARB)										
11	City of Modesto										
12	Tulare County Association of Governments							Retail, service, education, gov., other	Cities, county, census, surveys		
13	Council of Fresno County Governments	Do not use		Do not use		Do not use		Do not use			
14	Merced County Association of Governments	Do not use		Do not use		Do not use		Employment category	MCNA emp. Projections		
15	San Joaquin Council of Governments										
16	Santa Barbara County Association of Governments (SBCAG)										
17	Sacramento Area Council of Governments (SACOG)	Do not use		Do not use		Do not use		Do not use			
18	Southern California Association of Government (SCAG)	Do not use		Do not use		Do not use		Do not use			
19	Ventura County Transportation Commission	Do not use		Do not use		Do not use		Do not use			

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Household							
Survey No.		Population	Population Data Source	No. of Households	No. of Households Data Source	Household Type	Household Type Data Source	Family Size	Family Size Data Source
	I.0.1	IV.3.1.a	IV.3.1.b	IV.3.2.a	IV.3.2.b	IV.3.3.a	IV.3.3.b	IV.3.4.a	IV.3.4.b
1	Kern Council of Governments								
2	Metropolitan Transportation Commission (MTC)	Do not use		Do not use		Do not use		Do not use	
3	Transportation Agency for Monterey County								
4	Tahoe Regional Planning Agency	with census to TAZ levels		Census to TAZ to get productions		Do not use		Do not use	
5	California Energy Commission		DOF		DOF				
6	Butte County Association of Governments								
7	Santa Clara County (Center for Urban Analysis)	MTC except for home based work	ABAG	ABAG					
8	Orange County Transportation Authority (OCTA)	Used in sub-model to determine household size	SCAG and Cal State Fullerton	Used in sub-model to determine household size	SCAG and Cal State Fullerton	Single and multiple used in attraction regression	SCAG and Cal State Fullerton	Single and multiple used in attraction regression	SCAG and Cal State Fullerton
9	San Diego Association of Governments (SANDAG)			Do not use					
10	California Air Resources Board (CARB)								
11	City of Modesto	In trip production and attraction	Based on SF + MF units	In trip production	Strategic planning division. City of Modesto	Single family, multi-family	Strategic planning division. City of Modesto	In calculate population	Census
12	Tulare County Association of Governments			Vehicles per household/SF & MF		SF 2+,1,0/MF 2+,1,0			
13	Council of Fresno County Governments	Socioeconomic input		Socioeconomic input		Socioeconomic input		Do not use	
14	Merced County Association of Governments	# households derived from trip gen variable single multi	DOF/ MCAG projections					Do not use	
15	San Joaquin Council of Governments			Do not use		Do not use			
16	Santa Barbara County Association of Governments (SBCAG)			Used in trip gen.	RGF 1994, SBCAG	Single family, multi-family			
17	Sacramento Area Council of Governments (SACOG)								
18	Southern California Association of Government (SCAG)	Estimate trip making units	SE Forecast	Estimate trip making units	SE Forecast	Estimate trip making units	SE Forecast	Do not use	
19	Ventura County Transportation Commission	Do not use		Do not use		Do not use		Do not use	

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Household							
Survey No.		Auto Ownership	Auto Ownership Data Source	Children: number & age	Children Data Source	Household Income	Household Income Data Source	Other	Other Data Source
	I.0.1	IV.3.5.a	IV.3.5.b	IV.3.6.a	IV.3.6.b	IV.3.7.a	IV.3.7.b	IV.3.8.a	IV.3.8.b
1	Kern Council of Governments								
2	Metropolitan Transportation Commission (MTC)					Do not use			
3	Transportation Agency for Monterey County								
4	Tahoe Regional Planning Agency	Do not use		Do not use		like previous page income - $ to trip rate			
5	California Energy Commission						CEC (DRI)		
6	Butte County Association of Governments								
7	Santa Clara County (Center for Urban Analysis)			Do not use					
8	Orange County Transportation Authority (OCTA)	Single and multiple used in attraction regression	SCAG and Cal State Fullerton	Do not use		Cross-classification (3 groups)	SCAG and Cal State Fullerton		
9	San Diego Association of Governments (SANDAG)							HH by structure type	Census/land use
10	California Air Resources Board (CARB)								
11	City of Modesto	In trip generation	Census			In land use data	Census		
12	Tulare County Association of Governments	Per household type							
13	Council of Fresno County Governments	Socioeconomic input		Do not use		Do not use			
14	Merced County Association of Governments	Do not use		Do not use		Do not use			
15	San Joaquin Council of Governments								
16	Santa Barbara County Association of Governments (SBCAG)					Generalized into 4 level	CTPP, RGF '94		
17	Sacramento Area Council of Governments (SACOG)							Persons per household, workers per household	
18	Southern California Association of Government (SCAG)	Estimate trip making units	SE Forecast	Do not use		Estimate trip making units	SE Forecast		
19	Ventura County Transportation Commission	Do not use		Do not use		Do not use			

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Zonal								
Survey No.		Land-use	Land Use Data Source	Residential Density	Residential Density Data Source	Accessibility	Accessibility Data Source	Retail Employment	Retail Employment Data Source	Non-retail Employment
	I.0.1	IV.4.1.a	IV.4.1.b	IV.4.2.a	IV.4.2.b	IV.4.3.a	IV.4.3.b	IV.4.4.a	IV.4.4.b	IV.4.5.a
1	Kern Council of Governments									
2	Metropolitan Transportation Commission (MTC)									
3	Transportation Agency for Monterey County									
4	Tahoe Regional Planning Agency	Do not use		Do not use		Do not use		Attractions		Attractions
5	California Energy Commission									
6	Butte County Association of Governments							Do not use - in terms of # of employees	General plans	Do not use - in terms of # of employees
7	Santa Clara County (Center for Urban Analysis)		ABAG and local sources			Do not use			ABAG	
8	Orange County Transportation Authority (OCTA)	Do not use		Do not use		Transit accessibility used in auto ownership model	SCAG and Cal State Fullerton	Attraction/regression	SCAG and Cal State Fullerton	Attraction/regression
9	San Diego Association of Governments (SANDAG)	Do not use								
10	California Air Resources Board (CARB)									
11	City of Modesto			SF, MF, calculation	City's general plan			In trip generation and attraction	City's general plan + ITE trip generation	In trip generation and attraction
12	Tulare County Association of Governments			If better than ITE	Local agencies (LA)		If better than ITE	Local agencies		
13	Council of Fresno County Governments	Do not use		Do not use		Do not use		Socioeconomic input		Socioeconomic input
14	Merced County Association of Governments	Sub-allocating projected growth	General plans	Two variables single, multi-family	General plans	Do not use		A trip gen. Variable	MCAG emp. Projections	4 other categories
15	San Joaquin Council of Governments							Do not use		Do not use
16	Santa Barbara County Association of Governments (SBCAG)	Converted to employment data	local justifications							
17	Sacramento Area Council of Governments (SACOG)									
18	Southern California Association of Government (SCAG)	no entry		Do not use		Modal Split	SE Forecast	Trip Distribution	SE Forecast	Trip Distribution
19	Ventura County Transportation Commission	Models land use	City Generated	Do not use		Do not use		Land use and retail	General plan build out	Do not use

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Zonal								
Survey No.		Non-retail Employment Data Source	Total Employment	Total Employment Data Source	CBD/Non-CBD	CBD/Non CBD Data Source	Dwelling Units	Dwelling Units Data Source	Retail/Non-retail Areas	Retail/Non-retail Data Source
	I.0.1	IV.4.5.b	IV.4.6.a	IV.4.6.b	IV.4.7.a	IV.4.7.b	IV.4.8.a	IV.4.8.b	IV.4.9.a	IV.4.9.b
1	Kern Council of Governments									
2	Metropolitan Transportation Commission (MTC)									
3	Transportation Agency for Monterey County									
4	Tahoe Regional Planning Agency		Attractions		Do not use		Productions		Do not use	
5	California Energy Commission									
6	Butte County Association of Governments	General plans	Do not use				Do not use - SF/MF	General plans	Do not use - # of employees	General plans
7	Santa Clara County (Center for Urban Analysis)	ABAG		ABAG and local sources				ABAG and local sources	Do not use	
8	Orange County Transportation Authority (OCTA)	SCAG and Cal State Fullerton	Attraction/regression/auto ownership	SCAG and Cal State Fullerton	Do not use		Used in production calculation	SCAG and Cal State Fullerton	Do not use	
9	San Diego Association of Governments (SANDAG)									
10	California Air Resources Board (CARB)									
11	City of Modesto	City's general plan + ITE trip generation	In trip generation and attraction	Calculated	In paths build	Same as base year	In trip generation	General plan	Do not use	
12	Tulare County Association of Governments						If better than ITE	Local agencies		
13	Council of Fresno County Governments		Socioeconomic input		Trip generation rate		Socioeconomic input		Do not use	
14	Merced County Association of Governments	MCAG emp. Projections	Do not use		Do not use		Two trip gen. Variables	allocated	4 non-retail categories	employment projections/planned uses
15	San Joaquin Council of Governments									
16	Santa Barbara County Association of Governments (SBCAG)		5 categories	locals/RGF '94		Same as households				
17	Sacramento Area Council of Governments (SACOG)									
18	Southern California Association of Government (SCAG)	SE Forecast	Trip Distribution	SE Forecast	Do not use		Estimating trip making units	SE Forecast	Do not use	Do not use
19	Ventura County Transportation Commission	Land use	General plan build out		Do not use		Land use	General plan build out	Do not use	Do not use

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Zonal				4.1 Trip Generation Variables -- Network Characteristics		4.1 Trip Generation Variables -- Other Variables		
Survey No.		ITE Trip generation	ITE Trip Generation Data Source	Other	Other Data Source	Level of Service	Level of Service Data Source	Other Variable 1	Other Variable 1 Data Source	Other Variable 2
	I.0.1	IV.4.10.a	IV.4.10.b	IV.4.11.a	IV.4.11.b	IV.5.1.a	IV.5.1.b	IV.5.2.a	IV.5.2.b	IV.5.3.a
1	Kern Council of Governments									
2	Metropolitan Transportation Commission (MTC)									
3	Transportation Agency for Monterey County									
4	Tahoe Regional Planning Agency	Do not use				Do not use				
5	California Energy Commission									
6	Butte County Association of Governments	Do not use - used as a base for rates		Local knowledge for rate adjustments may						
7	Santa Clara County (Center for Urban Analysis)	Do not use						Service employment	ABAG	Walk
8	Orange County Transportation Authority (OCTA)	Do not use				Transit LOS used in auto ownership model			Department of Finance	Population/housing/employment region totals
9	San Diego Association of Governments (SANDAG)	Do not use				Do not use				
10	California Air Resources Board (CARB)							COG/MPO provided		
11	City of Modesto	Do not use								
12	Tulare County Association of Governments	Check-housing	ITE			V/C	Model			
13	Council of Fresno County Governments	Do not use				Do not use				
14	Merced County Association of Governments	Basis for trip gen. Rates	5th edition was used			Do not use			CA Dept. of Finance	Population projections used as a basis for future land use. (population sub-
15	San Joaquin Council of Governments									
16	Santa Barbara County Association of Governments (SBCAG)	Trip rates	Also used local data			HEIM analysis				
17	Sacramento Area Council of Governments (SACOG)			Employment accessibility						
18	Southern California Association of Government (SCAG)					Highway and transit network assignments	SE Forecast	Total vehicles by county	Estimating trip making units	Employment by 1 digit and 2 digit SIC codes
19	Ventura County Transportation Commission									

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.1 Trip Generation Variables -- Other Variables				
Survey No.		Other Variable 2 Data Source	Other Variable 3	Other Variable 3 Data Source	Other Variable 4	Other Variable 4 Data Source
	I.0.1	IV.5.3.b	IV.5.4.a	IV.5.4.b	IV.5.5.a	IV.5.5.b
1	Kern Council of Governments					
2	Metropolitan Transportation Commission (MTC)					
3	Transportation Agency for Monterey County					
4	Tahoe Regional Planning Agency					
5	California Energy Commission					
6	Butte County Association of Governments					
7	Santa Clara County (Center for Urban Analysis)	Regression	University	1990 rates		
8	Orange County Transportation Authority (OCTA)	SCAG	Sug-regional total	Cal State Fullerton	TAZ level data derived from SCAG totals and disaggregation of	
9	San Diego Association of Governments (SANDAG)					
10	California Air Resources Board (CARB)					
11	City of Modesto					
12	Tulare County Association of Governments					
13	Council of Fresno County Governments					
14	Merced County Association of Governments		EDD	Jobs forecast, used as input to employment projections		
15	San Joaquin Council of Governments					
16	Santa Barbara County Association of Governments (SBCAG)					
17	Sacramento Area Council of Governments (SACOG)					
18	Southern California Association of Government (SCAG)	New truck model				
19	Ventura County Transportation Commission					

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.2 Principal Data Sources				
Survey No.		Data Source 1	Data Source 1 Description	Data Source 2	Data Source 2 Description	Data Source 3
	I.0.1	IV.6.1.a	IV.6.1.b	IV.6.2.a	IV.6.2.b	IV.6.3.a
1	Kern Council of Governments					
2	Metropolitan Transportation Commission (MTC)	ABAG Proportion Series				
3	Transportation Agency for Monterey County					
4	Tahoe Regional Planning Agency	TRPA growth forecasts	Residential and commercial allocations are the basis for assigning future growth			
5	California Energy Commission	CEC develops forecasts using DRI and UCLA forecasts				
6	Butte County Association of Governments	Census (1990)		General Plan	Retail/Non-retail	Dunn & Bradstreet (consultant)
7	Santa Clara County (Center for Urban Analysis)	ABAG	Standard tract level projection data	Congestion management program, VTA	annual authority by city approvals for development	
8	Orange County Transportation Authority (OCTA)					
9	San Diego Association of Governments (SANDAG)	We use "demographic and economic forecasting model" to produce regional growth forecasts, with 100's of input. I can provide documentation if		Sub-regional growth forecasts are from a sub-regional allocation model, preliminary driver by existing and planned land use.		
10	California Air Resources Board (CARB)	COG/MPO	VMT summarized by speed	Caltrans MVSTAFF truck KM of travel	VMT for regions not covered by travel models	HPMS
11	City of Modesto	General plan land use + base year	Provided by strategic planning division of City's community development department.			
12	Tulare County Association of Governments	DOF	Employment/population estimates	TCAG-Las	Population	Census
13	Council of Fresno County Governments					
14	Merced County Association of Governments					
15	San Joaquin Council of Governments					
16	Santa Barbara County Association of Governments (SBCAG)	Raired growth forecast (RGF '94)	Population, households, employment	Household income (RGF '96)	Household distribution by region in trip gen.	Census data
17	Sacramento Area Council of Governments (SACOG)	DOF else, in house	Population forecasts			
18	Southern California Association of Government (SCAG)	CA EDD & Federal Bureau of Labor Statistics	Jobs by SIC code (database 1972-98) use shift-share method to do regional & county employment forecast	Bureau of the Census -- Current Population Survey	Income (MHI) by county, used by Transportation Modeling for various stages of generation/dist/mode split/	Bureau of Labor Statistics
19	Ventura County Transportation Commission					

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STATEWIDE TRAVEL DEMAND MODEL SURVEY KEY

Question	Organization	4.2 Principal Data Sources			4.3 Additional Information
Survey No.		Data Source 3 Description	Data Source 4	Data Source 4 Description	
	I.0.1	IV.6.3.b	IV.6.4.a	IV.6.4.b	IV.7
1	Kern Council of Governments				
2	Metropolitan Transportation Commission (MTC)				See documentation on web.
3	Transportation Agency for Monterey County				
4	Tahoe Regional Planning Agency				We are anticipating that the 1995 base year will be the last for Lake Tahoe. The socio-economic information is based on a 1974 survey. We don't have the resources or the need to
5	California Energy Commission				
6	Butte County Association of Governments	Business listings, # employees/business, etc.			The BCAG countywide model - developed using MINUTP v.98 is pretty straight forward. Our input files if housed and employment were developed using each of the adopted
7	Santa Clara County (Center for Urban Analysis)				Walk access to Caltrain, LRT stations, and bus lines - use assessor parcel data to extradite # HH within 1/4 mile of stations and lives.
8	Orange County Transportation Authority (OCTA)				
9	San Diego Association of Governments (SANDAG)				Many zones with detailed network is used to provide "sub-regional" model detail throughout region. Transportation models used for many local planning studies, so inputs are
10	California Air Resources Board (CARB)	Estimate speed distributions for MVSTAFF/VMT	DMV Master registration file	Vehicles in use	
11	City of Modesto				
12	Tulare County Association of Governments				We keep an air quality model that doesn't change (due to conformity). We also have future land use model that we continually update.
13	Council of Fresno County Governments				See model validation report provided by mail.
14	Merced County Association of Governments				
15	San Joaquin Council of Governments				
16	Santa Barbara County Association of Governments (SBCAG)	TAZ development	1991 state travel model	External trips estimation	
17	Sacramento Area Council of Governments (SACOG)				
18	Southern California Association of Government (SCAG)	CPI for SCAG Region/ for constant $ conversion	CA EDD & Bureau of Labor Statistics	Labor force data by county, used to forecast workers for generation	
19	Ventura County Transportation Commission				

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures Applicability of Market Segmentation to Performance Measure Outcomes

Technical Memorandum

Booz·Allen & Hamilton Inc.
June 30, 1999

TABLE OF CONTENTS

1. INTRODUCTION

The notion of market segmentation, long embraced by the private sector, recognizes that there are no "average" customers. The process of "averaging", though useful in many areas of analysis often disregards the inherent differences among customer groups or segments. The purpose of market segmentation is to identify clusters of people that have particular needs or desires. Within these clusters, averaging can be used to find the common ground within that market group. For example, describing the "average" public transit rider as living in a "carless" household ignores other potential transit markets that may respond to unique transit services such as express buses for workers. Commuter markets may have access to an automobile, but would take transit if services that meet their commute needs were provided.

This document discusses how market segmentation relates to the performance measurement initiative undertaken by the California Department of Transportation.

The document is divided into four parts as follows:

- Categories for transportation market segmentation
- Linkage between market segmentation and performance measurement
- Implementation challenges
- Conclusions.

Each part is addressed in detail in the main body of this document.

2. CATEGORIES FOR TRANSPORTATION MARKET SEGMENTATION

The transportation market is segmented in four primary ways: by mode, by trip purpose, by customer profile, and along geographic/jurisdictional lines. These four categories do not represent all possible categories as any number of additional categories could be added to this list. Furthermore, there is overlap among the four. For example, one might talk about *urban commuters* or *rural transit users*.

2.1 Separation by Mode

Transportation planners at the local, regional and State levels often segment the transportation market by <u>mode</u>. Caltrans, for instance, has a Division of Mass Transportation, a Division of Rail and a Division of Aeronautics, each charged with planning for a given mode or modal market segment. This straight modal separation has the advantage of being easily understood by the public at large.

More recently, many transportation agencies have also recognized the need to address person and freight movement separately. As such, a modal segmentation for the freight market would include rail, trucking, water, and air transportation.

2.2 Trip Purpose

In addition, many transportation planners who develop and maintain transportation travel demand models segment the transportation market by trip purpose. Traditional person trip purpose segmentation includes home-based work, home-based shopping, recreation, and non-home based trips.

2.3 Customer Profile

Attributes of customers are sometimes used by planners and decision-makers to segment market data. Examples of customer profiles commonly analyzed include gender, age, household income, household size, auto ownership, and other census categories of information. The national census, which is updated every ten years, provides the main basis for segmentation at the customer profile level.

2.4 Geographic / Jurisdictional Basis

Planners have also relied on land use and geography for market segmentation (e.g., urban, suburban, rural, commercial, residential)

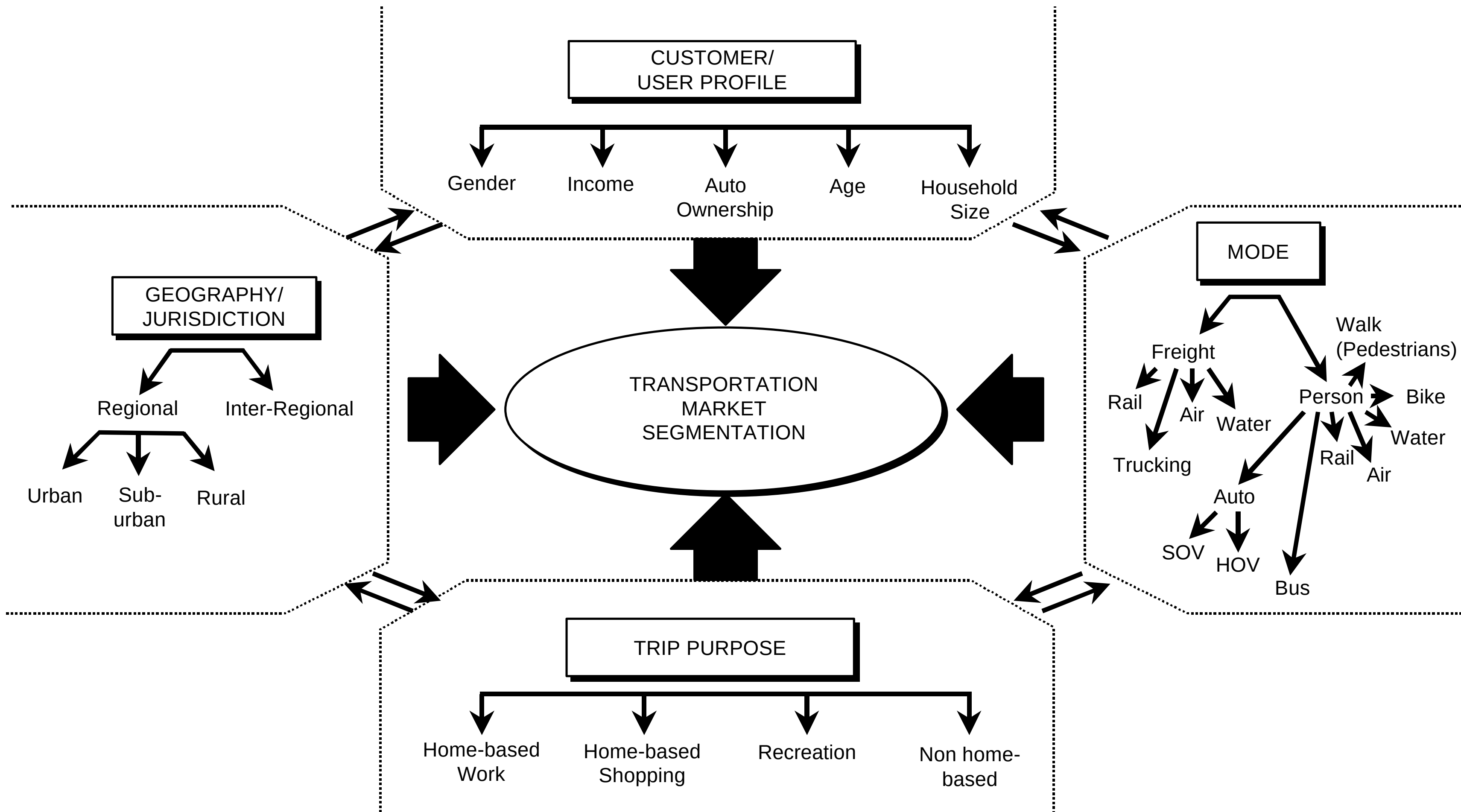
Because of California Senate Bill 45 (1997), there is an additional market segment: regional versus inter-regional transportation. To date, an official definition of "inter-regional" has not been adopted, yet distinguishing the two is critical in the new funding climate. Exhibit 1 presents the four major categories for market segmentation.

3. LINKAGE BETWEEN MARKET SEGMENTATION AND PERFORMANCE MEASUREMENT

The performance measurement process includes two primary processes: monitoring and forecasting. Market segmentation is relevant for each. For instance, as the State, regions, and local agencies monitor the transportation system's performance, it is very useful to understand how this performance affects different segments of customers.

A performance monitoring process that can communicate mobility and accessibility performance for any (or all) of the segmentation categories presented in the previous section (e.g., trip purpose) is more valuable to decision-makers than system-wide averages. For instance, decision-makers are likely to be more interested in travel delays reported by mode, accessibility by transit dependency or urban commute market, or accidents by geographical region. Providing such information to planners allows them to develop focused strategies for maintaining or improving current performance.

Exhibit 1 – Market Segmentation Categories



Note: Please note that these categories are not meant to be comprehensive. Rather, they represent the four segmentation approaches that are most commonly used or discussed in California. Also note that each category encompasses many sub-segments, each of which is deemed important by a variety of stakeholders.

RPSF457-018001Fb.Y

A performance forecasting process that incorporates market segmentation also adds significant value. Understanding how investments today will affect different market segments in the future is invaluable to decision-makers. For instance, market segmentation can aid in understanding how transit investments will help transit-dependent households such as households with no automobile ownership. Given that equity is a growing concern at both the regional and State levels, the importance of the performance forecasting process should not be underestimated.

Understanding the value of incorporating market segmentation is one thing. However, actually incorporating market segmentation poses significant challenges. The next sections outline challenges of applying market segmentation as well as some possible solutions.

4. IMPLEMENTATION CHALLENGES

Phase II of the State performance measurement initiative focused on a "proof of concept" during which candidate indicators were tested for viability (e.g., data availability, applicability to multi-modal analysis).

In general, most candidate indicators were found viable for implementation, at least for urban areas. Major data obstacles still exist for rural counties and portions of larger counties.

Incorporating market segmentation for each outcome and associated indicators is also challenging for the reasons outlined in the following sections:

4.1 Mobility/Accessibility

The *mobility indicators* tested in Phase II include travel time and delay (or lost time). For monitoring purposes, the testing relied heavily on loop detector data for highways, and on-time performance data for non-private-auto modes (e.g., bus and rail transit). Therefore, in a State of the System Report one can articulate travel time and delay by mode and in the aggregate. To some extent, the State of the System Report can also incorporate geography/jurisdiction segmentation by reporting travel time and delay by county, by corridor, by region, and by State. However, there is no data that distinguish between regional and inter-regional mobility. When an automobile drives over a loop, it is impossible at this point to tell whether that auto is traveling a few miles or all the way to the Oregon border. Though the mobility is the same for all vehicles traveling along that segment at that time, there is no way to calculate the mobility for a particular travel market.

Moreover, none of the data sources explicitly addresses the other two categories for market segmentation (i.e. trip purpose, customer profile). There may be other methods for "estimating" performance by market segment such as the census data and the regional, statewide, and nationwide origin-destination surveys. However, these are not conducted often enough or comprehensively enough to allow for annual, biannual, or comprehensive trend analysis.

For travel forecasting purposes, travel time and delay are generally estimated using regional travel demand models. These models usually segment the trip generation by trip purpose (e.g., home to work, home to shopping). The final assignment of the trips to the transportation network are reported by mode and geography, although no regional models explicitly address the regional versus inter-regional segmentation except as "external" trips to the model. These models do not address rail or air inter-regional trips, nor do they assign freight trips. Finally, these models cannot forecast travel time or delay by customer profile.

The *accessibility* indicators tested to date include accessibility (using distance or time) to the transportation system and to desired destinations (although the latter is still unresolved). Monitoring accessibility was demonstrated, primarily by using the 1990 census data and regional updates to that data.

Accessibility to the transportation system changes when new infrastructure and services are provided or when major shifts in population densities and/or profiles occur. It is easier to monitor changes to the infrastructure or services provision than population changes.

- Using geographical information systems (GIS), changes due to additions to the transportation system can be monitored. Several tools are already in place in the State (i.e., San Diego Association of Governments) that can quickly estimate the accessibility to new regional bus stops or rail stations.

- Monitoring changes in population is more challenging. Given that census updates occur only once every ten years, one would need to rely on local planning data (e.g., from Regional Planning Agencies such as the Association of Bay Area Governments) for the years between updates.

4.2 Reliability

The reliability indicator tested was variability in travel time. The viability of monitoring reliability relies on the same data sources as the travel time indicator for mobility. Therefore the conclusions for reliability are the same, namely that:

- For monitoring purposes, reliability can be articulated by mode and to some extent by geography/jurisdiction. No consistent or frequently updated data sources exist for reporting on reliability by trip purpose or customer profile.

- There are no tools that can forecast variability in travel time. Therefore, reliability forecasting for market segmentation is applicable at this time.

4.3 Cost Effectiveness

Generally, only future projects and plans address cost effectiveness. Therefore, this outcome relates only to the forecasting process. In estimating cost effectiveness, Caltrans and some regional agencies rely in part on benefit-cost analysis. That is, future benefits are estimated, then translated into dollars. The sum of all dollar benefits is then divided by the cost of the project(s).

To estimate future benefits, agencies rely heavily on a number of models and databases, including regional travel demand models, air quality models (e.g., EMFAC7), accident trend data and simulation tools. Caltrans has recently updated its multi-modal Life-Cycle Benefit Cost Model to address the costs and benefits associated with a wide range of capital projects. The results can be related by modal segment and by geography (without distinguishing between regional and inter-regional). For some projects, results can also be related to customer profiles (e.g., for bus projects) and to lesser extent to trip purpose. For a statewide implementation, market segmentation for this outcome is restricted to forecasting by modal and by geography segmentation.

4.4 Economic Well Being

The indicator for this outcome is final demand. The Phase II testing concluded that final demand is only viable for forecasting purposes. Moreover, final demand addresses macro-economic forecasts and does not distinguish between the traditional market segmentation categories described before. The only possible segmentation that can be incorporated is the freight versus the person movement delineation.

4.5 Sustainability

The indicator for this outcome is average percentage of household resources directly dedicated to transportation. As such, the most relevant segmentation category applicable to this indicator is customer profile. However, this indicator is yet to be tested in the same manner as the aforementioned indicators. It is unclear whether it is viable to monitor and forecast average percentage of household resources directly dedicated to transportation by market segment. Expected challenges to such application include: elapsed time between census data, difficulty in tracking volatile energy prices, and lack of a common source for fare structures and usage for transit.

4.6 Environmental Quality

All environmental quality indicators are best segmented by mode. The California Air Resources Board (CARB) and Caltrans estimate emissions by mode for the State and regions. In addition, CARB aggregates the emissions placed on the atmosphere based on the BURDEN model component of its Motor Vehicle Emissions Inventory. Tallies are provided on a county-by-county basis and for the State.

As noted above, it is possible to monitor environmental quality emission indicators by modal segment. For forecasting, most regions use travel demand models and linkage from these models to air quality models. Therefore, it is possible to forecast emission indicators by modal segment as well.

4.7 Safety and Security

The indicators for this outcome include accident and crime rates, both of which can be monitored by modal segment and geography. They cannot be monitored by trip purpose or by customer profile, however.

There are no generally accepted tools for forecasting accidents and crime; therefore forecasting indicators for this outcome is not possible.

4.8 Equity

The equity outcome relates directly to social groupings by income level. It is inherently segmented by user profile and does not require further segmentation. The equity outcome is still under review and it is unclear how it will be monitored and forecasted at this time.

4.9 Customer Satisfaction

The Customer Satisfaction outcome will rely on surveys for monitoring purposes. There are no tools by which to forecast customer satisfaction. Surveys can be tailored and stratified by any of the four market segmentation categories. Therefore, this outcome is the most conducive to market segmentation and probably one of the most useful for decision-makers as well.

5. CONCLUSIONS

Based on our analysis, some type of market segmentation will be possible for both monitoring and forecasting system performance measures. Most outcomes are conducive to some type of modal segmentation.

Exhibit 2 below summarizes the applicability and viability of market segmentation by outcome.

Exhibit 2 – Market Segmentation Applicability by Outcome

TYPE OF OUTCOME	MODE		TRIP PURPOSE		CUSTOMER PROFILE		GEOGRAPHIC	
	Current	Forecast	Current	Forecast	Current	Forecast	Current	Forecast
Mobility	●	●	○	●	○	○	◕	◕
Accessibility	●	●	○	○	●	○	◕	◕
Reliability	●	○	○	○	○	○	◕	○
Cost Effectiveness		●		◔		◑		◕
Economic Well-Being					◕	◕		
Environmental Quality	●	●						
Safety And Security	●	○					◕	○
Equity					●	◑		
Customer Satisfaction	●	○	◕	○	●	○	●	○

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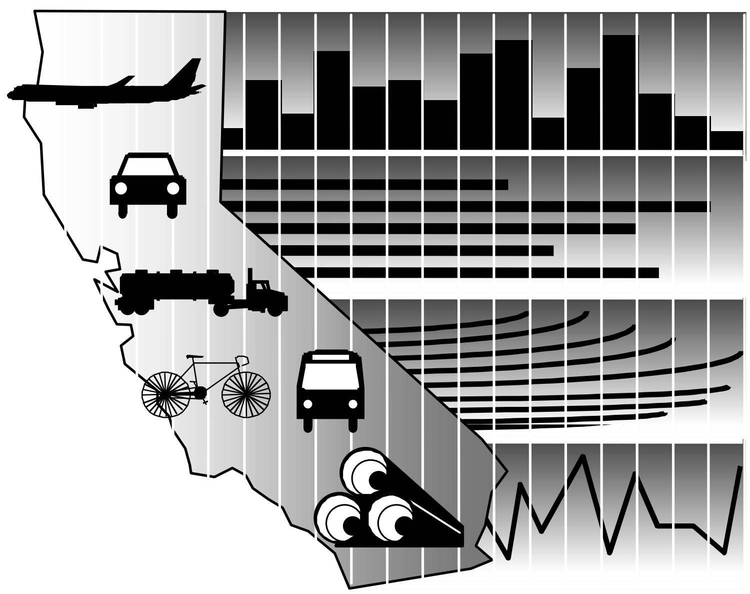
●
◕ – Able to apply most market segmentation
◑ – Partially able to apply market segmentation but missing some data
◔ – Limited applicability of market segmentation
○ – Market segmentation possible but data is unavailable
Blank – Market segmentation not applicable to outcome or segment

Note however, that consistent application of such segmentation is years away, given the inherent differences in tools and methodologies applied by the regions. The most promising outcome for market segmentation is customer satisfaction, primarily because it relies on the conduct of a comprehensive survey that can be stratified by any market segment deemed relevant.

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures
Review of Caltrans Monitoring and Analysis Tools
Technical Memorandum



Booz·Allen & Hamilton Inc.

June 30, 1999

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LIST OF EXHIBITS

This technical memorandum reviews current analysis tools used by the California Department of Transportation (Caltrans) and evaluates their potential for use in the statewide performance measurement initiative currently underway.

1. BACKGROUND

In August of 1998, the California Department of Transportation (Caltrans) released the *California Transportation Plan: Transportation System Performance Measures Final Report*. This report represented Caltrans' first phase in an ambitious effort by the Business, Transportation, and Housing Agency to develop a statewide performance measurement program.

The two goals of this program are:

> *To develop indicators/measures to assess the performance of California's multi-modal transportation system, to support informed transportation decisions by public officials, operators, service providers, and system users.*
>
> *To establish a coordinated and cooperative process for consistent performance measurement throughout California.*

To meet these goals, Caltrans convened policy and technical advisory committees comprised of people representing different regions as well as different jurisdictional levels and the private sector. Public forums were held around the state to solicit input from the public, and a statewide conference in 1997 brought together nearly 200 people from local and national planning agencies, academia, and the private sector to discuss the role and implementation of performance measures.

This effort resulted in the *Final Report* which outlined nine desirable outcomes that the transportation sector should strive toward in order to meet the goals. The report also identified several candidate performance measures to indicate whether these outcomes were being achieved. These outcomes and candidate measures are shown in Exhibit 1.

Exhibit 1: Desired Outcomes of the Transportation System and Candidate Performance Measures

Desired Outcome	Definition	Candidate Measures/Indicators
Mobility / Accessibility	Reaching desired destinations with relative ease within a reasonable time, at a reasonable cost with reasonable choices.	• Travel Time • Delay • Access to Desired Locations • Access to the System
Reliability	Providing reasonable and dependable levels of service by mode.	• Variability of Travel Time
Cost-Effectiveness	Maximizing the current and future benefits from public and private transportation investments.	• Benefit / Cost Ratio • Outcome Benefit per unit of Cost
Sustainability	Preserving the transportation system while meeting the needs of the present without compromising the ability of future generations to meet their own needs.	• Household Transportation Costs
Environmental Quality	Helping to maintain and enhance the quality of the natural and human environment.	• National and State Standards
Safety and Security	Minimizing risk of death, injury, or property loss.	• Accident and Crime Rates
Equity	Distributing benefits and burdens fairly.	• Benefits per Income Group
Customer Satisfaction	Providing transportation choices that are safe, convenient, affordable, comfortable, and that meet customer needs.	• Customer Survey
Economic Well-Being	Contributing to California's economic growth.	• Final Demand (Value of Transportation to the Economy)

In Phase I of this program, Booz·Allen & Hamilton worked with Caltrans to develop a proof-of-concept to test the applicability of one such measure -- highway reliability. In Phase II, currently underway, Booz·Allen is expanding this highway proof-of-concept to several regions throughout the state and is testing other performance measures for transit and economic well being.

Another important component of this Phase II effort is to identify analysis tools that Caltrans currently uses to evaluate the transportation system and to evaluate their potential for statewide performance measurement. This technical memorandum is the result of this effort and reports on the following analytical tools used at Caltrans:

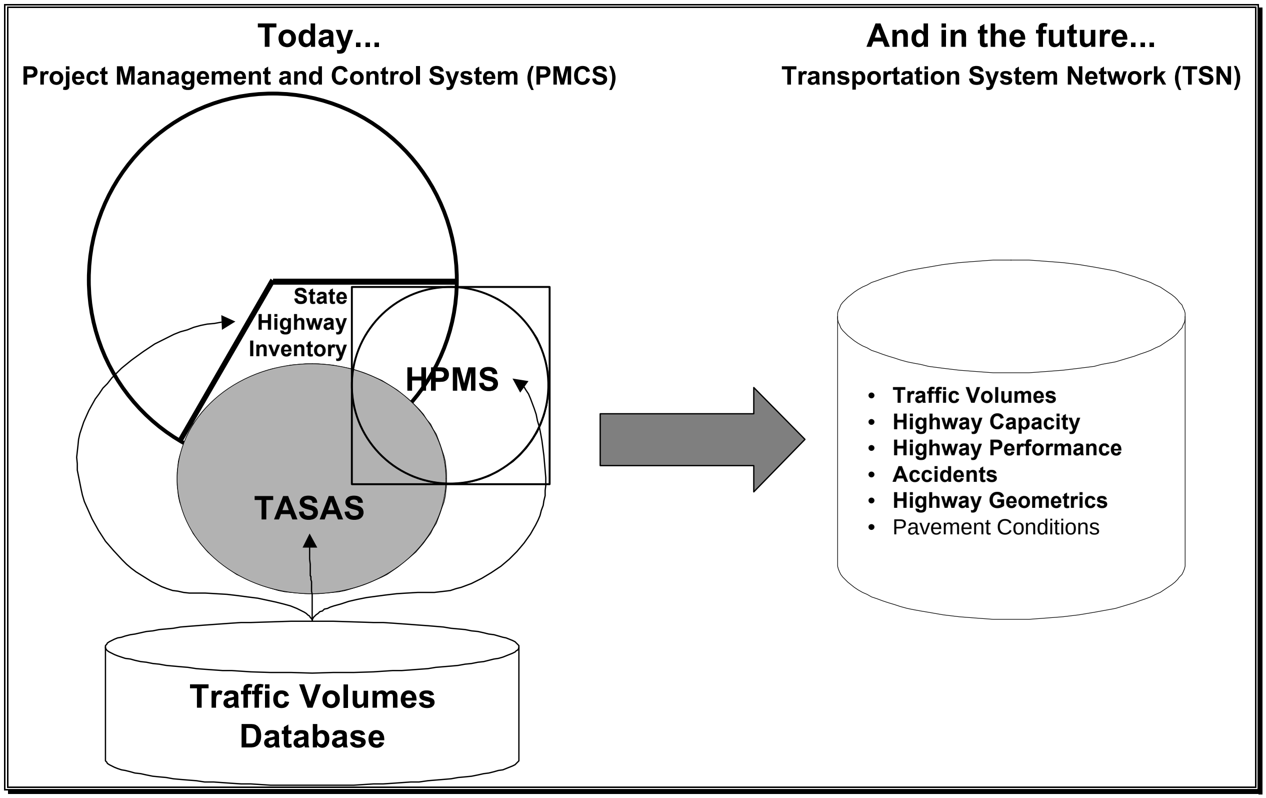
- Traffic Volumes Database
- State Highway Inventory Database
- Traffic Accident and Surveillance Analysis System (TASAS) Database
- Highway Performance Monitoring System (HPMS) Database
- Intermodal Transportation Management System (ITMS)
- Life-Cycle Benefit / Life-Cycle Cost Model (LCBM)
- Highway Congestion Monitoring Program (HICOMP)
- Caltrans Geographic Information System (GIS) Library
- Other tools and data sources.

The first four of these tools are databases maintained by Caltrans for monitoring the highway system and provide much of the data needs for statewide highway planning. Currently, the four databases are not fully integrated, but they share data and there is some overlap between them. Caltrans is developing a new enterprise resource system to integrate several databases from within the organization. The Transportation System Network (TSN) will integrate each of these four tools. Currently, HPMS and Traffic Volumes are the only two functional entities in TSN. TASAS and the State Highway Inventory are expected to be substantially integrated and functional within TSN by January 1, 2000.

The Project Management and Control System (PMCS) is used by Caltrans to monitor project specific information (e.g., construction contracts). The State Highway Inventory currently makes up the highway condition and performance-tracking element of PMCS.

Exhibit 2, shown on the following page, provides a rough approximation of the relationships among these tools.

Exhibit 2
Relationship among Caltrans Analysis Tools



Two other tools, the ITMS and the LCBM, are being updated. The HICOMP report is undergoing a comprehensive review to determine how it can best fit the needs of Caltrans headquarters, Districts, and other partner agencies. The ITMS and LCBM provide Caltrans with the ability to forecast the performance impacts of projects.

Finally, Caltrans relies heavily on its Geographic Information Systems library to support a growing number of applications.

The sections that follow discuss each of these tools. The discussion will include a description of the tool and the tools current use. An evaluation of how it might be used in performance measurement also will be discussed. The table in the Appendix of this report summarizes the results of this review.

2. RESULTS OF THE REVIEW

This section presents the findings of the Booz·Allen review of Caltrans analysis capabilities.

2.1 Traffic Volumes Database

This database is updated continually, however the data is validated and adjusted only once a year. The continuous update comes from count (or control) stations throughout the main state-maintained highway network. This database provides the foundation for the annual *Traffic Volumes on California State Highways* that is a standard reference for Caltrans planners throughout the state. Caltrans adjusts these counts to develop Average Annual Daily Traffic (AADT), which is the basis for many travel demand forecasts throughout the state.

Caltrans Districts maintain the Traffic Volumes database and it feeds all other Caltrans planning tools, including the State Highway Inventory, TASAS, and HPMS. This data source collects only state highway information. Local and other non-state roads are not included. Since the Traffic Volumes database is used to feed HPMS, this data source is very important because regional travel demand models used in areas identified as non-attainment areas have to use HPMS to calibrate their regional model results.

For performance monitoring purposes, the Traffic Volumes database can provide average daily traffic, which is used in the State Highway Inventory to produce projections of volume and travel speed. The Traffic Volumes database also supplements data collected for HPMS.

2.2 State Highway Inventory

The State Highway Inventory is a database that contains state highway data. It makes up about one-third of the Project Management and Control System (PMCS), used to monitor performance of highways maintained by Caltrans. This database contains highway volume, capacity, and pavement information. It is populated with data from TASAS, the traffic volume database, and HPMS. As shown in Exhibit 2 above, there is significant overlap between the various tools as they are all interrelated and loosely linked.

Exhibit 3, shown on the following page, describes some of the data items found in the State Highway Inventory that may be relevant to the performance measurement initiative.

Exhibit 3
Relevant Data Items from State Highway Inventory

Data Item	Description
Annual Average Daily Traffic (AADT)	Taken on a sample of highways. Used to calculate capacity and performance
Weighted Design Speeds	Used for capacity and performance indicators. Weighted design speed is calculated.
Percent Trucks	Used to estimate delay and operating speeds.
K-Factor	Provides the design hour volume
Directional Factor	Percent design hour volume in peak direction
Peak Capacity	Calculated using Highway Capacity Manual
Volume / Service Flow Ratio	Used for congestion reporting
Future AADT	Used to determine pavement and capacity needs
Future AADT Year	Forecast year for future AADT
Travel Activity by Vehicle Type (Areawide level only)	Can be used to estimate regional and Statewide person and freight travel

The State Highway Inventory covers only state-maintained highway segments. HPMS covers all statewide routes including state highways, county, and local roads. The principal difference between the two databases is that the State Highway Inventory provides a 100 percent sample of state highway condition and performance data. In contrast, HPMS uses statistical sampling to update highway condition and performance data since it covers a much larger number of road segments (both state and non-state).

The State Highway Inventory can be used to forecast some performance measures, especially those related to mobility and accessibility (i.e., delay due to congestion and travel time). One feature of this database is its analytical capability to forecast level-of-service (LOS) ratings for highways.

2.3 Traffic Accident and Surveillance Analysis System (TASAS)

TASAS is an extremely detailed database providing information on the state's highways at five-foot intervals. TASAS is a dual database that consists of highway and accident data. It contains data describing the physical feature of a given roadway including terrain, median and lane widths, toll plazas as well as detailed accident data. TASAS feeds the State Highway Inventory and HPMS, but the TASAS data used in these two databases are aggregated to make them more useable for general planning purposes. Like the State Highway Inventory and HPMS, TASAS receives traffic volume data from the Traffic Volumes database. TASAS is not currently Y2K compliant and will be phased out once the data and processes have migrated to the new corporate database (TSN) under development.

The principal TASAS reporting capabilities will be retained in the new system, however. While not a forecasting tool, TASAS can still be called on to provide information about accidents, which would help in monitoring the Safety and Security outcome.

2.4 Highway Performance Monitoring System (HPMS)

Developed in 1978 by the Federal Highway Administration (FHWA) in coordination with the states, HPMS is a continuously updated, curb-to-curb roadway information system. HPMS contains basic infrastructure, classification, and jurisdictional information on every highway, road, and street in the state. In addition, statistical sampling is used to collect data on travel demand, truck use, and service performance of the highway system.

Caltrans regularly updates its HPMS database to report on the extent, use, condition, and performance of all public roads in the state. In addition to a wide range of roadbed condition and configuration data, several demand and performance related items could be used in performance measurement. HPMS shares a number of data elements with the State Highway Inventory described above and summarized in Exhibit 3.

HPMS provides information for all public roads in the state of California. The State Highway Inventory only monitors state-maintained roads. Therefore, a combination of the two systems would have to be called upon to monitor or forecast performance for statewide coverage.

Several of these items from HPMS shown in Exhibit 3 can be used to estimate travel delay as an indicator for the Mobility and Accessibility Outcomes in future years, especially if the future AADT data item is estimated. However, HPMS would be more readily used as a monitoring tool, especially for urban areas since regional travel demand models are used to develop forecast year speeds and volumes.

HPMS has undergone a number of revisions and enhancements over the years. In April 1999, FHWA released the *Highway Performance Monitoring System Reassessment Final Report*. This report proposes several changes to make data collection easier and to eliminate items believed to offer little benefit. Most changes were made to streamline the data reporting procedures only; so most data items will not be affected. One data item being deleted from HPMS that would have had some use in performance measurement is the number of at-grade railroad crossings. The Federal Railroad Administration does track this information, however, as does the California Public Utilities Commission (See Other Tools and Data Sources below).

2.5 Intermodal Transportation Management System (ITMS)

The ITMS has potential as a forecasting tool for Caltrans. The GIS-based ITMS, developed in 1994 by Caltrans, currently is being updated. The ITMS contains a wealth of information for both person and goods travel for several modes of travel including:

Person Movement	Freight Movement
– Auto	– Shipping
– Bus	– Pipelines
– Intercity Rail	– Trucking (truckload, less-than truckload, private,
– Aviation	and intermodal; and by commodity type)
– Urban Rail	– Rail (total tons, intermodal by commodity type)

The ITMS database contains, by direction, annual average travel projections for person and goods movement for a base year and three future years (10, 20, and 30 years into the future). For passenger travel, average weekday and peak hour volumes are available for urban areas within California. This information is compiled from several regional, Caltrans, other state and federal data sources. A principal advantage of the ITMS as a forecasting tool for performance measures is that it compiles travel demand data from every official regional travel model in the state including models from the metropolitan planning organizations:

- Southern California Association of Governments (SCAG)
- Metropolitan Transportation Commission (MTC)
- San Diego Association of Governments (SANDAG)
- Sacramento Area Council of Governments (SACOG).

This data is integrated into a GIS package and analysis tool. This tool allows users to create "actions" to mitigate a transportation problem. These actions can be grouped into coherent "strategies" at any level of analysis ranging from the corridor to the statewide level. The evaluation feature of the ITMS allows Caltrans to estimate several areas of performance including mobility, financial, environmental, economic, and safety. The model can either output the information as a report or visually using the GIS graphical user interface. A sample of the text output from the ITMS is shown below.

Illustrative

Exhibit 4
ITMS Sample Evaluation Results

ACTION NAME: SACOG_Ramp1
DESCRIPTION Implement Ramp Metering in Sacramento Region

PERFORMANCE MEASURES

A. MOBILITY MEASURES

	DAILY	PEAK
TOTAL PMT IMPACTED	593120.10	57633.36
TOTAL VMT IMPACTED	417690.21	41763.30

PERSON THROUGHPUT (or MOBILITY INDEX)

	DAILY	PEAK	
BEFORE	92.30	89.70	
AFTER	92.30	89.70	
DIFFERENCE	0.00	0.00	
PERCENT DIFFERENCE		0.00	0.00

LOST TIME DUE TO CONGESTION (in hours)

	DAILY	PEAK	
BEFORE	9124.92	886.67	
AFTER	9124.92	886.67	
DIFFERENCE	0.00	0.00	
PERCENT DIFFERENCE		0.00	0.00

B. FINANCIAL MEASURES

COST TO SERVICE PROVIDERS (in dollars)

Capital Costs	100000.00	
Operating Costs	100000.00	
Annual Equivalent Costs		200000.00
AEC Per 1000 Daily PMT		337.20

USER COSTS

	DAILY	PEAK	
Net Change	0.00	0.00	
Change Per 1000 PMT		0.00	0.00

C. ENVIRONMENTAL MEASURES

NET CHANGES TO RUNNING EMISSIONS (in lbs)

	DAILY	PEAK
Carbon Monoxide	0.00	0.00
Hydro Carbons	0.00	0.00
Nitrogen Oxides	0.00	0.00
Particulate Matter	0.00	0.00
Total Change	0.00	0.00
Change Per 1000 PMT	0.00	0.00

NET CHANGES TO FUEL CONSUMPTION (in gallons)

	DAILY	PEAK
Total Change	0.00	0.00
Change Per 1000 PMT	0.00	0.00

NET CHANGES TO GREEN HOUSE GAS EMISSIONS (CARBON DIOXIDE in lbs)

	DAILY	PEAK
Total Change	0.00	0.00
Change Per 1000 PMT	0.00	0.00

D. ECONOMIC MEASURES

Jobs Supported Via

Capital Spent	3.79
Operating Spent	3.76

Gross Area Product Impacts Via

Capital Spent	230000.00
Operating Spent	220000.00

E. SAFETY MEASURES (daily accidents based on statewide trend averages)

BEFORE		
	Accidents	0.4093
	Deaths	0.0526
	Injuries	0.1627
AFTER	Accidents	0.4093
	Deaths	0.0526
	injuries	0.1629

2.6 Life-Cycle/Benefit-Cost Model (LCBM)

The Life-Cycle/Benefit-Cost Model is a spreadsheet-based tool to provide simple economic benefit and cost analysis for a range of transportation projects. LCBM is an "open" model so Caltrans users can override default model parameters to produce results that are more accurate. The model is being updated to incorporate the analysis capabilities of the Caltrans' Rail Benefit/Cost model.

The model allows the user to enter information about the project, expected traffic demand, accident rate information, transit data (if the project is a transit project), and expected project construction and operating costs. The model outputs the following information:

- Life-Cycle Costs
- Life-Cycle Benefits
- Net Present Value
- Benefit to Cost Ratio
- Rate of Return on Investment
- Pay Back Period.

Several intermediary model results are also calculated in the model. These include:

- Total travel time benefits for highways and transit. Modes analyzed in the model include HOV highway, non-HOV highway, truck, passenger rail, light rail, and bus

- Changes in highway vehicle operating costs as benefits for highway and transit projects

- Benefits due to accident reductions for highway and transit vehicles

- Benefits due to emissions reductions for highway and transit vehicles.

To estimate these benefits, there are several parameters used in the model that are referenced to develop the economic impacts. These are summarized below:

- General economic values
- Highway operations measures
- Travel time values
- User operating costs
- Highway accident costs

- Fuel consumption rates
- Transit accident rates and costs
- Highway and transit emissions tables.

Data sources used to develop these parameters draw on current literature on transportation economic impacts and include the following:

- *Motor Vehicle Stock, Travel, and Fuel Forecast* (Caltrans, 1998)
- National Transportation Safety Council data
- Motor Vehicle Emissions Inventory based on the California Air Resources Board (CARB) Emfac7 emissions model
- 1991 Statewide Travel Survey
- Various technical studies.

LCBM provides Caltrans with the ability to forecast economic impacts for specific projects. The tool could be modified to conduct regional economic impact analyses for groups of projects. However, at the statewide level several enhancements would have to be included in the model to produce statewide forecasts.

2.7 Highway Congestion Monitoring Program Report (HICOMP)

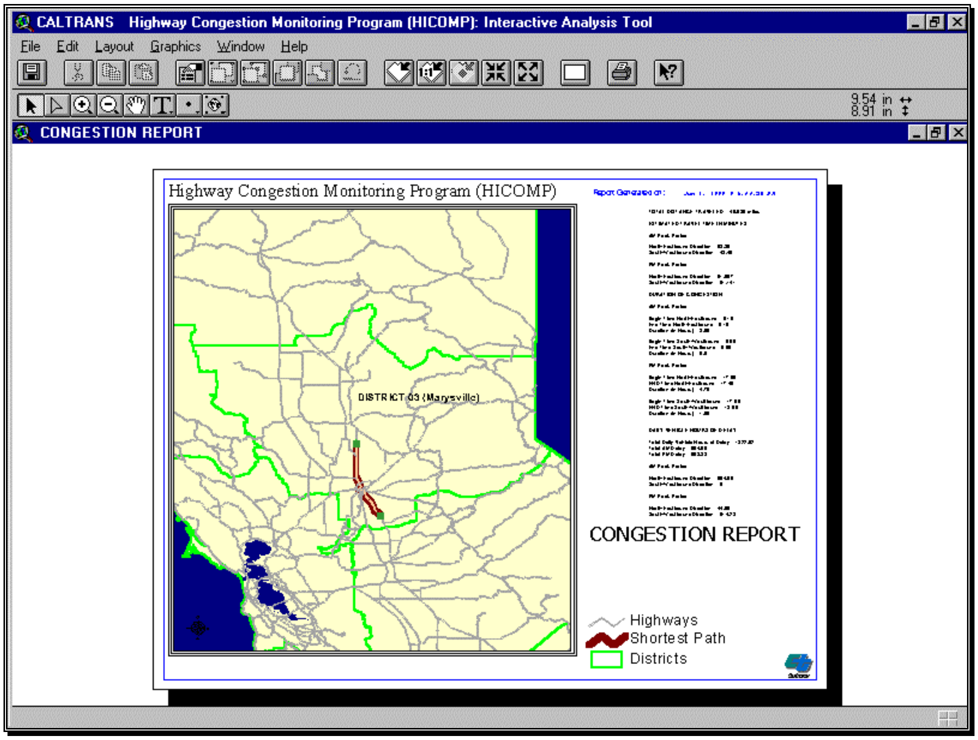
The HICOMP report is an annual document that identifies and measures recurrent congestion on California's freeway system. The 1998 report was recently completed and efforts are getting underway for the 1999 report. The HICOMP report provides information on the extent, magnitude, and duration of congestion. One of the principal outputs of the HICOMP report is the estimation of daily vehicle-hours of delay.

Data for the HICOMP report is collected two times per year using tachometer vehicles. In District 7 (Los Angeles), a system of electronic loop detectors in the pavement of the freeways of the region collects continuous data that is used to develop the HICOMP report for that District.

A prototype GIS-based Congestion Monitoring tool was recently developed for Caltrans. This tool demonstrates the ability of GIS to enhance congestion monitoring. An example of this tool is presented in Exhibit 5.

Recently, loop detector data was used to test the highway reliability indicator for the performance measures program. This test demonstrated the feasibility of using loop detector data to measure delay and reliability.

Exhibit 5
HICOMP Prototype Showing Congestion Monitoring Capabilities

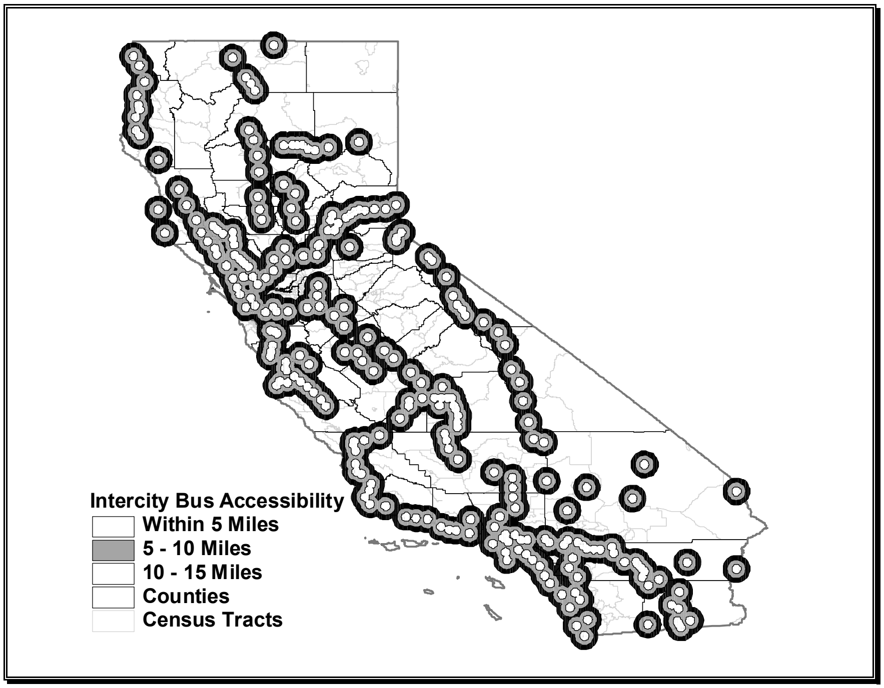


2.8 Caltrans GIS Library

Caltrans Transportation Systems Information Program (TSIP) maintains an extensive library of geographic coverages that can be used to monitor performance on the statewide network. The ITMS and other Caltrans initiatives (e.g., CTIS) make use of these coverages. GIS provides a powerful tool for visualizing performance spatially, and GIS developed maps are recommended for inclusion in both the regional and inter-regional State of the System reports.

An ideal use of GIS in performance monitoring is in the measurement of accessibility to the transportation network. Exhibit 6 on the following page shows an example of how GIS can be used to measure accessibility to the inter-city bus network.

Exhibit 6
Using GIS to Measure Accessibility to the Intercity Bus Network



2.9 Other Tools and Data Sources

A variety of other tools and data sources within and outside of Caltrans can be useful in the development of performance measures for monitoring and forecasting. Three specific examples are chosen for discussion here:

- California Motor Vehicle Stock, Travel and Fuel Forecast
- Annual Report of Railroad Accidents Occurring in California
- Waybill Sample.

The *California Motor Vehicle Stock, Travel, and Fuel Forecast* is developed by the Transportation System Information Program. This report provides future VMT, and fuel consumption estimates. These can be used to monitor and forecast the environmental quality outcome.

The Public Utilities Commission *Annual Report of Railroad Accidents Occurring in California* provides data and summaries of railroad and light-rail transit accidents and personal injuries throughout the state. This report uses Federal Railroad

Administration accident reporting forms, but limits the analysis to California railroads. This source would be useful in the development of measures for the Safety outcome.

The third data source is the Interstate Commerce Commission's Railroad Freight Waybill sample. It provides detailed shipping information based on a sample of waybills provided to the Commission by private carriers. The Waybill Sample provides aggregate data on commodity tonnages between given origins and destinations. Commodity values are also represented in the database as is information on hazardous materials shipments. This data source could be utilized to support the market section of the State of the System Report for freight.

APPENDIX

Tool Description	Data Sources for Tool	Tool Data Outputs	Primary Performance Measurement Use	Linkage To Outcome Or Indicator
Highway Performance Monitoring System (HPMS)	• Primary data collection from highways (e.g., tachometer, loop data) • Statistical samples	• Annual Average Daily Traffic (AADT) • Speed Limit • Weighted Design Speed • Percent Trucks • K-Factor • Directional Factor • Peak Capacity • Volume/Service Flow Ratio • Future AADT • Future AADT Year • Travel Activity by Vehicle Type	Monitoring and Forecasting	• Mobility / accessibility: travel time, delay
Life-Cycle Benefit Cost Model (LCBM)	• MVSTAFF • NTSC data • MVEI - CARB • 1991 Statewide Travel Survey • Various technical studies	• Travel Time Savings • Vehicle Operating Cost Savings • Accident Reductions • Emission Reductions • Life-Cycle Costs • Life-Cycle Benefits • Net Present Value • Benefit/Cost Ratio	Forecasting	• Cost effectiveness: benefit cost ratio (project by project basis)

Tool Description	Data Sources for Tool	Tool Data Outputs	Primary Performance Measurement Use	Linkage To Outcome Or Indicator
		• Rate of Return on Investment • Payback Period		
Traffic Volumes Database	• Primary data collection	• AADT volumes • Percent of trucks in flow	Monitoring	• Mobility / accessiblity: travel time
Truck Count Book	• Primary data collection	• Truck volumes • Percent of trucks in flow	Monitoring	
Highway Congestion Monitoring Program Report (HICOMP)	• Primary data collection 2x per year • Loop detector data	• Lost time due to congestion • Travel time • Highway reliability	Monitoring	• Mobility / accessibility: delay, travel time • Reliability: standard deviation of travel time
Intermodal Transportation Management System (ITMS)	• Regional travel demand models • TRANSEARCH freight database & supplemental data • Caltrans corporate database (SHI, TASAS, HPMS) • District speed studies • Route segment reports • Amtrak/Caltrans California Intercity Rail forecasting model	• Emissions • Mobility Index • Lost time due to congestion • State economic Impacts (GSP, Jobs supported) • Fuel consumption • User costs • Accidents	Forecasting	• Cost effectiveness • Safety • Environmental quality: emissions, fuel consumption • Economic development • Mobility / accessibility: delay, access to intermodal system • Equity: distribution of benefits by population segment

Tool Description	Data Sources for Tool	Tool Data Outputs	Primary Performance Measurement Use	Linkage To Outcome Or Indicator
	• REMI regional economic model • U.S. Census Bureau • MVEI-CARB • Direct surveys of intermodal sites			• Safety / security: accident rates • Sustainability: change in user costs
California Motor Vehicle Stock, Travel, and Fuel Forecast (MVSTAFF)	• California Department of Finance population projections • UCLA Andersen Forecast of the Economy • WEFA Group U.S Forecast • U.S. Department of Commerce Truck Inventory and Use Survey	• Total Annual Vehicle Miles Traveled • Fuel Consumption • By auto, motorcycle, and four truck classifications	Forecasting	• Environmental quality: fuel consumption • Mobility / accessiblity: travel time
California Public Utilities Commission Annual Report of Railroad Accidents Occurring in California	• Federal Railroad Administration accident reporting forms	• Railroad accidents • Light-rail accidents • Train and crew lost days due to injury or illness • Hazardous material releases	Monitoring	• Safety / security: accident rates for rail
Caltrans GIS	• Miscellaneous	• Spatial coverages	Monitoring Display	• Mobility / accessibility
Traffic Accident and Surveillance and	• Traffic Count	• Accidents	Monitoring	• Safety / security

Tool Description	Data Sources for Tool	Tool Data Outputs	Primary Performance Measurement Use	Linkage To Outcome Or Indicator
Analysis System (TASAS)	Database • Primary data collection • California Highway Patrol	• Fatalities • Injuries		
State Highway Inventory	• Traffic Count Database • Primary data collection • TASAS	• Volumes (AADT) • Forecast volumes • Level of Service • Capacity	Monitoring and forecasting	• Mobility / accessibility
FRA Waybill Sample	• Sample of rail freight waybills	• Commodity tonnages Commodity costs • Hazardous materials	Monitoring	• Economic well-being:

California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures Implementation Plan

Technical Memorandum

Booz·Allen & Hamilton Inc.

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IMPLEMENTATION PLAN

This document summarizes the discussions and conclusions of Phase II of the performance measurement initiative led by the California Department of Transportation (Caltrans).

Phase II focused on testing the concepts and performance indicators for several of the nine outcomes defined in the Phase I report published in August 1998. Most of these tests have been successfully completed and documented in more than ten different products available through Caltrans, including:

- Applicability of Indicators to Highway
- Applicability of Indicators to Transit
- Applicability of Indicators to Goods Movement
- Economic Well-Being Literature Review
- Economic Well-Being Test Results
- Travel Demand Model Review
- State of the System Report Design
- Sacramento Conference Paper: Pre-Testing Performance Measures
- Market Segmentation
- Review of Caltrans Monitoring and Analysis Tools

Therefore, this report does not repeat the information contained in all these reports. However, several issues still must be addressed, including:

- early integration with other State initiatives
- incremental implementation concepts tested in Phase II
- internal consensus building within Caltrans, especially at the districts
- external consensus building over and beyond the agencies represented on the technical advisory committee
- continuing to test the other outcomes and indicators not fully addressed in Phase II, especially as they relate to system condition and maintenance
- establishing clear linkages to current State and regional planning processes
- addressing the needs and lack of tools and data in smaller rural regions.

How these seven issues are addressed will significantly influence the success of the entire initiative. They are all critical and challenging. However, the transportation sector has never been more ready. The remainder of this document discusses each of these issues in more detail and presents an overall implementation schedule thereafter.

1. EARLY INTEGRATION WITH OTHER STATE INITIATIVES

The 1998 elections have led to changes in direction for transportation. Infrastructure in general, and transportation in particular are gaining visibility at the Executive and Legislative branches of the State. Moreover, the make-up of the transportation committees in the House, Senate and the California Transportation Commission (CTC) are likely to affect overall policy and focus of transportation decision making. Two initiatives, under way at the State level, are relevant to system performance measurement. The first, Senate Resolution 8 (SR 8) identified transportation needs over the next ten years. The second, the Governor's Commission on Building for the 21st Century, is reviewing and planning for infrastructure needs in California from a long term perspective. Caltrans staff is working with the Transportation Sub-Committee to address transportation specific needs. Both initiatives provide important integration opportunities for performance measurement.

An integral aspect for performance measurement has always been informing decision makers of the impacts of their decisions and establishing accountability for the investments made.

Given that both initiatives aim to raise funds for transportation, it would be very beneficial to evaluate and communicate the estimated performance impacts of the investments finally proposed by both initiatives.

This will require working closely with Caltrans and CTC staff currently working with the Legislature and the Governor's Committee to identify opportunities for applying performance measurement to some of their work.

2. INCREMENTAL IMPLEMENTATION CONCEPTS TESTED IN PHASE II

Phase I of the performance measurement initiative recommended a phased or incremental deployment approach. At this time, after the testing conducted in Phase II, the first step of deployment should focus on the monitoring component of performance measurement.

Therefore, during this next year, the State will develop an Inter-Regional State of the System Report focused primarily on the outcomes and measures already tested. This effort will identify data gaps that must be addressed. Moreover, it will help establish a baseline for performance against which future reports will be compared.

The inter-regional transportation system is meant to cover the main transportation axes in the State for highways, bus, and inter-city rail that cross regional boundaries. The Inter-Regional State of the System Report will use the same measures tested in Phase I and will represent a "report card" by performance outcome, focusing on mobility, reliability and safety. Given the anticipated challenges in collecting and analyzing the required information, any shortcomings will be evaluated and addressed before the 2002 STIP cycle.

3. INTERNAL CONSENSUS BUILDING WITHIN CALTRANS

Caltrans headquarters, in association with representatives from regional and other stakeholder agencies, have led the performance initiative to date. However, for true deployment, headquarters must now work closely with Caltrans district representatives who will ultimately implement many of the performance measurement aspects.

Therefore, a number of meetings will be held during which headquarters will explain how performance measurement will be implemented as part of the planning, monitoring and programming processes.

Specifically, options for how to incorporate performance measurement into Project Study Reports (PSRs), Project Scope and Summary Reports (PSSRs) and Transportation Concept Reports (TCRs) will be discussed. At the end of these efforts, Caltrans will document the agreed to framework and train staff as the transition to performance measurement begins.

It is also important to examine the application of performance measures with respect to Traffic Operations. System management of key investments (e.g., ramp metering, transportation management centers, auxiliary lanes) is a critical component of SHOPP that will need to be addressed.

Discussions should also be held between Caltrans and representatives from the Business Transportation and Housing Agency and the California Transportation Commission. The purpose of these discussion meetings is to present Phase II findings, develop support for the performance measurement initiative, and identify any refinements requested and/or needed to achieve wider support.

4. EXTERNAL CONSENSUS BUILDING

As we near full deployment, Caltrans will also start involving more regional and local agencies in discussing and possibly refining the performance measurement concept and implementation framework.

To date, the level of external involvement has been limited until such time that indicators are tested and refined. With the conclusion of Phase II, Caltrans must now present its findings to as many external stakeholder agencies as possible for comment, review, and adaptation.

External agencies will include Metropolitan Planning Organizations (MPOs), Congestion Management Agencies (CMAs), Regional Transportation Planning Agencies (RTPAs), and County Transportation Commissions among others. Key to these discussions will be linkages to decision making, flexibility in implementation, and consensus vis-à-vis the deployment schedule.

5. LINKAGES TO CURRENT STATE AND REGIONAL PLANNING PROCESSES

Ideally, performance measurement is most appropriate for long range planning. At the regional level, performance measurement fits best with the development of regional transportation plans (RTPs). By incorporating the relevant outcomes in an RTP, the programming process will be influenced automatically by system performance.

An RTP that fully adopts performance measurement would include:

- a section on the "State of System" reflecting the monitoring component of the performance initiative
- a section that describes the anticipated system performance impacts related to the investments and projects included in the fiscally constrained plan reflecting the forecasting component of performance measurement.

Caltrans has been working with its partners to develop RTP guidelines that encourage the use of system performance measures. Moreover, the State Transportation Improvement Program (STIP) draft guidelines also encourage the reporting of expected performance impacts of the investments programmed.

The picture is somewhat different at the State level. Caltrans does not currently develop and publish a statewide plan for the inter-regional system. As such, it does not have a periodic product that can present the findings of the monitoring and forecasting components of performance measurement.

Until such time that such a product is developed, Caltrans will develop a State of the System Report every two years. Caltrans will also incorporate performance measurement into the development of the inter-regional transportation improvement program (ITIP).

6. TESTING THE OTHER OUTCOMES

While developing the first "product" of the performance measurement initiative (i.e., the inter-regional State of the System Report), Caltrans will continue to review, analyze and test candidate indicators for other outcomes.

The mobility and reliability outcomes focus on system performance that can be addressed by improvement projects. For example, when delay is deemed excessive, the State or region may consider investing in rail, high occupancy vehicle (HOV), intelligent transportation system (ITS) deployment projects to relieve congestion and thereby reducing delay.

However, a considerable portion of transportation funds are expended on the maintenance of the multi-modal transportation system. The outcomes most related to measuring the performance of maintenance activities are "sustainability" and “cost effectiveness”.

The State will therefore review the applicability of performance indicators to reflect the condition of the infrastructure. This again will encompass all modes and address SHOPP expenditures in maintenance and system management.

Other outcomes and associated indicators will be tested as well, including cost effectiveness, and economic well being will be tested further. However, the customer satisfaction outcome will be postponed in order to allow the development of a comprehensive survey that meets both State and regional needs.

As results become available from such testing, it may be possible to incorporate some of them in the inter-regional State of the System Report as well.

7. SMALLER RURAL REGIONS

Based on preliminary review and analyses, significant gaps related to data and tools exist for rural regions. These regions have already communicated to Caltrans that although they agree with the concept of performance measurement, they simply do not have the resources to collect, analyze, and report on their system performance. For instance, rural highways generally do not have loop detectors that allow for data collection needed for mobility and reliability indicators.

In the 1998 performance measurement conference administered and facilitated by the University of California Los Angeles (UCLA) and University of California Berkeley, Caltrans management acknowledged this challenge and committed to reviewing the needs of the smaller regions.

Over the next year, Caltrans will identify these needs while developing the inter-regional State of the System report. Specific gaps and needs will be identified and a options as to how to address them will be evaluated.

However, it is critical that the implementation of performance measurement not exclude these regions. They are critical to overall State connectivity and represent a considerable and important share of Californians.

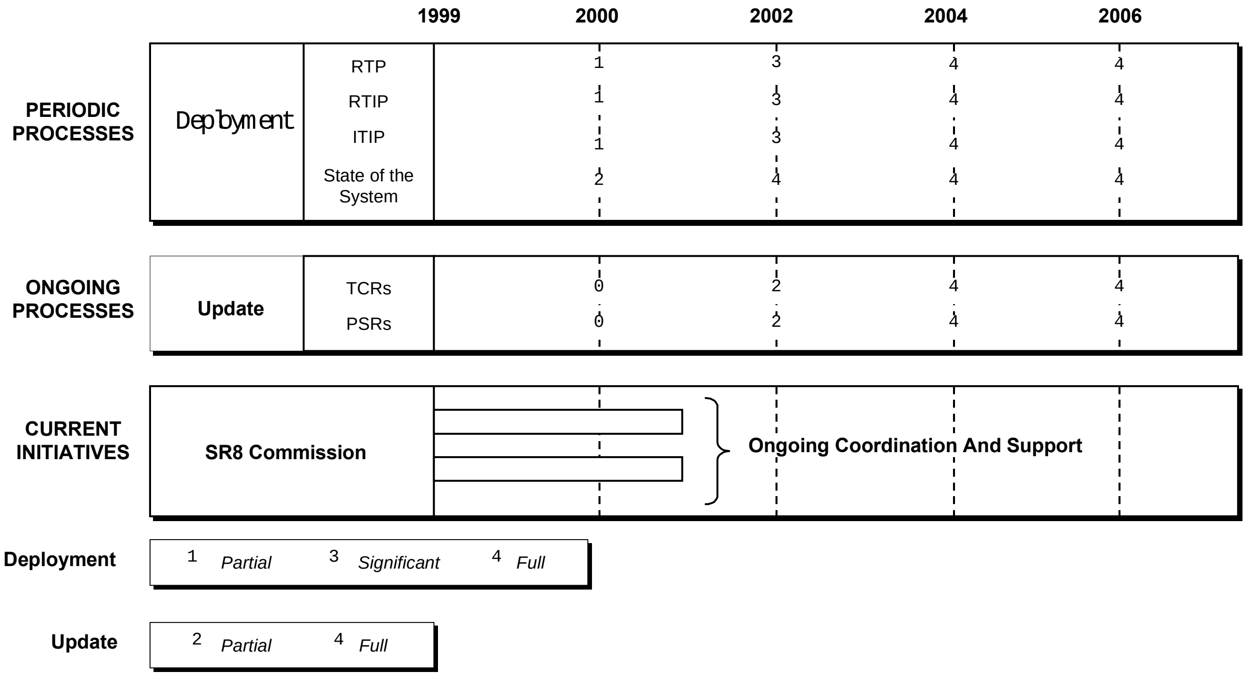
8. DEPLOYMENT SCHEDULE

The goal for the performance measurement initiative is a true linkage to transportation analysis and decision making. As such, linkages (at differing degrees) must be established with the following products and processes:

- transportation concept reports (TCRs)
- project study reports (PSRs)
- project scope and summary reports (PSSRs)
- regional transportation plans (RTPs)
- regional transportation improvement programs (RTIPs)
- inter-regional transportation improvement programs (ITIPs)
- other critical initiatives (e.g., SR 8)

To achieve true linkages, many databases, tools, and processes must be reviewed and possibly adapted. Full implementation will take time. However, the incremental implementation must start immediately. Exhibit 1 presents an approximate schedule for deployment and linkage proposed at this time. It will be discussed with stakeholders at the State, regional and local levels over the next year and refined as necessary. Note that regional and local agencies are likely to implement performance measurement differently, focusing on their own priorities.

Exhibit 1: Deployment Schedule and Linkages



The exhibit also shows that significant efforts must be undertaken in 1999, 2000 and 2001 if performance measurement is to affect the decision making cycle in 2002. Note that 2002 represents the first full funding STIP cycle and should therefore be targeted for performance measurement implementation. However, throughout the years, it is likely that measures will be refined, new tools developed, and linkages revised in a manner that adds value to decision makers and the public alike.